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INTERNATIONAL GEOLOGICAL CONGRESS

REPORT OF THE EIGHTEENTH SESSION
GREAT BRITAIN 1948



PART X (10)

PROCEEDINGS OF SECTION J

FAUNAL AND FLORAL FACIES
AND
ZONAL CORRELATION

LONDON
1952

UNIVERSITY OF ILLINOIS AT
CHICAGO CIRCLE
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INTERNATIONAL GEOLOGICAL CONGRESS//

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General Editor: A. J. Butler

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PART X

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FAUNAL AND FLORAL FACIES AND ZONAL CORRELATION

Edited by

H. DIGHTON THOMAS

LONDON
1952

Section J, Faunal and Floral Facies and Zonal Correlation,
met on three occasions during the Session. The successive Chair-
men at these meetings were as follows:-

August 26th	Sir Arthur E. Trueman Professor B. B. Sahni
August 27th	Professor R. Kozłowski Professor G. G. Delépine
August 30th	Professor Chr. Poulsen Sir Arthur E. Trueman

The Secretary of the Section was Dr. H. Dighton Thomas.

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FAUNES ET FLORES EN STRATIGRAPHIE DE DÉTAIL

Par ARMAND RENIER

Belgium

RÉSUMÉ

Le rôle de la paléontologie en stratigraphie n'a pas cessé de s'étendre et de se préciser. Flores et faunes sont, tout compte fait, d'égal intérêt. Paléobotanique et paléozoologie doivent être semblablement enseignées aux futurs géologues. Si la systématique reste fondamentale, un exposé rapide des divers modes de fossilisation doit lui servir d'introduction, afin de mettre l'observateur en état de tirer parti de tout élément utilisable. D'autre part, âge et faciès doivent être envisagés conjointement: la paléontologie éclaire, non seulement la chronologie, mais aussi la paléogéographie, voire, objet plus délicat, la paléoclimatologie. Des exemples typiques d'applications, de cas vécus, même erronés, sont aussi, pour l'élève, hautement instructifs.

L'ÉCHANGE de vues inscrit à l'ordre du jour de cette XVIII^e Session du Congrès géologique international sous le titre *Faunal and Floral Facies and Zonal Correlation*, est une reprise ou une révision de la question examinée, il y aura bientôt un demi-siècle, par la défunte *Section de Stratigraphie et de Paléontologie du Congrès* et administrativement résolue à Paris, le 18 août 1900, par l'adoption, non sans réserves, du rapport de la *Commission Internationale de Classification Stratigraphique*.

* * * * *

Après s'être mis plus ou moins d'accord sur la dénomination des divisions de premier, deuxième et troisième ordres, respectivement qualifiées de Groupes ou Ères, Systèmes ou Périodes, Séries ou Époques, le rapport, rédigé par Eugène Renevier et adopté par l'assemblée, déclarait:

d. *Divisions de 4^e ordre*.—AGES—Étages.

La Commission reconnaît que les divisions de 4^e ordre n'ont plus qu'une valeur régionale et ne sont donc pas absolument nécessaires à la classification internationale.

e. *Divisions de 5^e ordre*.—PHASES—Zones.

Quant à ces subdivisions, encore plus locales, il sera encore plus difficile d'avoir une terminologie fixe; mais au moins est-il à désirer que la forme du nom rappelle l'ordre de la subdivision et soit, autant que possible, la même pour les différentes Périodes ou les différentes régions.

Aussi la Commission, tenant compte de l'usage très général des zones paléontologiques, pour les terrains de l'ère mésozoïque, recommande de désigner autant que possible les divisions de 5^e ordre d'après un fossile caractéristique essentiel au niveau en question:

Exemples:

Zone à *Amaltheus margaritatus*.

Zone à *Psiloceras planorbis*.

Zone à *Productus horridus*.

Zone à *Cardiola interrupta*.

* * * * *

Entre ce texte et le libellé du sujet ici discuté, l'opposition est flagrante, presque absolue. C'est que les résultats de l'exploration statistique des suites sédimentaires se sont entre-temps affirmés plus clairement. Si dans une région type il est encore permis de dire de façon absolue "Zone à . . .", tout ailleurs, cette expression n'a qu'une valeur relative: "Zone à —" s'entend "Zone dite à —", tout comme, surtout jadis,—aux temps héroïques,—alors que la classification était à base minéralogique et ainsi que d'Omalius en faisait explicitement la remarque, on continuait à parler de "Calcaire carbonifère" même là où tout calcaire était absent, et aussi de "terrain houiller sans houille"! !

C'est illusion naïve et candide pour tout débutant que d'imaginer comme d'extension verticale très réduite de façon absolue toute forme animale et végétale qu'il vient à découvrir. L'extension verticale observée dépend tout à la fois du niveau stratigraphique, c'est-à-dire de l'âge du sédiment, et de son faciès.

Quoiqu'il en soit, certains auteurs de traités, même élémentaires, de Paléontologie ont mille fois raison de mettre sous les yeux de leurs lecteurs des représentations diagrammatiques où sont précisées et la localisation primitivement assignée à certaines formes et l'extension verticale, de beaucoup plus considérable, qui leur est à présent reconnue.

Sans doute pourrait-on chicaner longuement à ce sujet et, moyennant une pulvérisation des espèces, réduire l'extension verticale de chacune d'elle. La Systématique est une science haute et délicate, déjà quand il s'agit des vivants; à plus forte raison lorsqu'il s'agit de lignées éteintes, donc sans représentant dans la nature actuelle. Il serait oiseux d'en discuter ici, surtout quand, introduisant la notion faciès, il faudrait examiner le cas des espèces représentatives.

* * * * *

Zonal correlation peut se traduire stratigraphie de détail. La zone ou phase n'est-elle pas classiquement le moindre des termes dans la gradation des subdivisions stratigraphiques? Elle acquiert toujours un intérêt d'autant plus grand qu'elle est de puissance plus petite. C'est bien le cas lorsqu'elle se réduit à une strate, couche ou banc, et est alors qualifiée d'horizon; ainsi en est-il surtout dans les gisements miniers, car elle y permet une plus exacte définition de la richesse.

* * * * *

Comme les gisements souterrains peuvent permettre une exploration plus poussée notamment dans les anticlinaux, une manière de répondre à la question posée ne serait-elle pas de dire les résultats d'une exploration poursuivie durant de près de cinquante années dans le bassin houiller de Liège, sur l'horizon à *Gastrioceras subcrenatum*.

Le bassin houiller de Liège est un vrai bassin; c'est le seul, à partir de la frontière allemande, qui puisse, sur une distance de 76 km, se distinguer sur la retombée orientale de l'anticlinal transversal du Samson ou dorsale de la Belgique. Long d'environ 30 km, il est apparemment large au maximum de 13 km, son bord méridional étant partout masqué par des massifs charriés. (Fig. 1.)

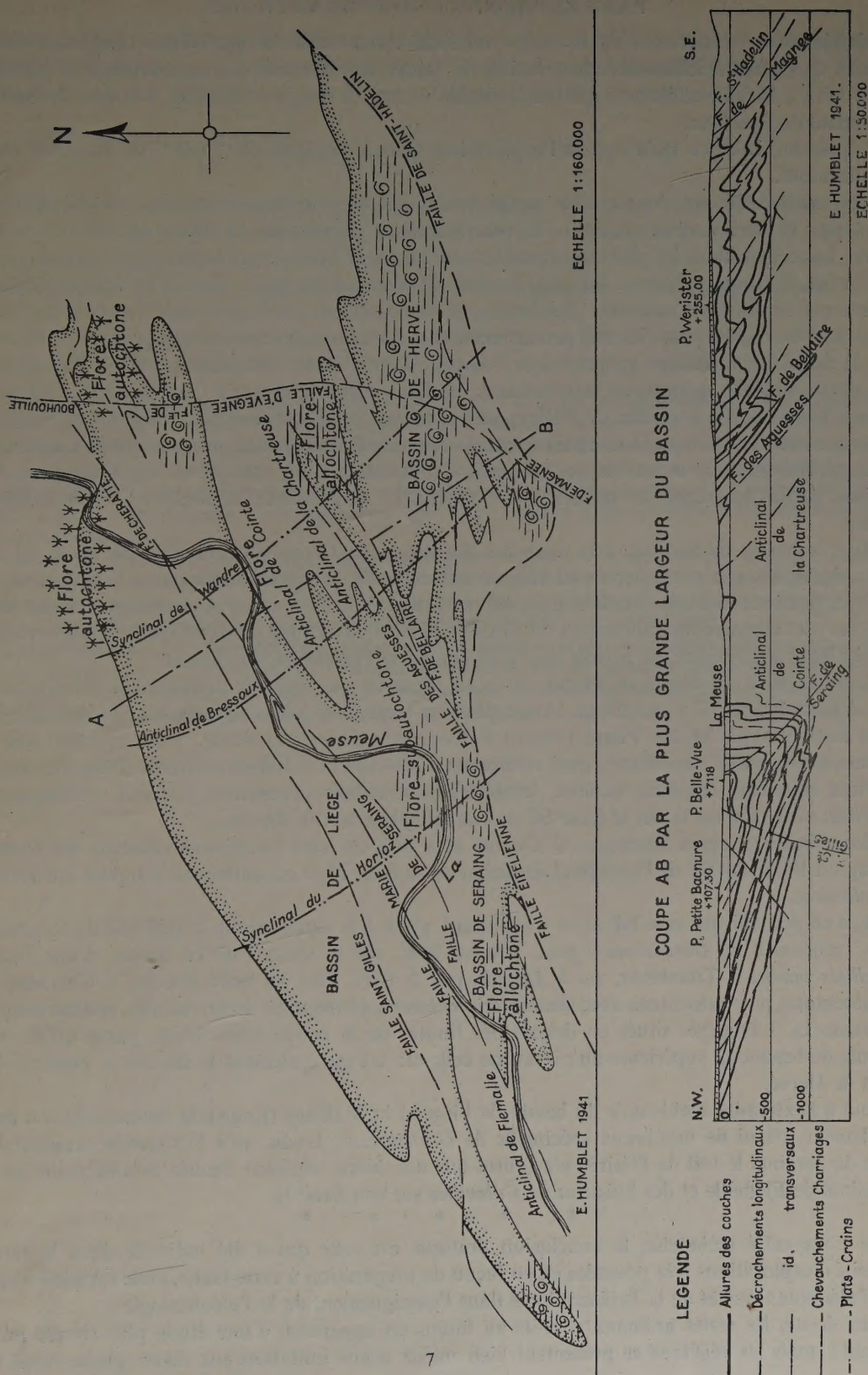
Les allures en sont clairement précisées sur la coupe horizontale, au niveau de—200 m publiée en 1941 par M. Emile Humblet dans son mémoire sur Le Bassin Houiller de Liège (*Revue Universelle des Mines*, 8eS., t. XVII, no. 12). Cette coupe horizontale nous servira de canevas, flanquée qu'elle est d'une coupe verticale plane, de trace A B, donc en travers du bassin suivant sa plus grande largeur. Sur cette coupe horizontale sont simplement résumées les allures marginales de la veine Désirée ou Bouxharmont, l'une des plus inférieures qui soient exploitées; c'est précisément celle que surmonte l'horizon dit à *Gastrioceras subcrenatum*.

Comme l'a rappelé M. Humblet, le débrouillement stratigraphique du bassin de Liège est à présent poussé si loin que l'horizon en question est partout défini avec certitude en dépit des variations des caractères paléontologiques de son toit. Pour aboutir à ce résultat, on a progressé de proche en proche en relevant tous les niveaux accessoires qui flanquent l'horizon considéré.

L'axe principal du bassin ou Synclinal de Liège est dirigé SW—NE, donc varisque. Son point le plus bas est au croisement d'un pli transversal de direction armoricaine, le Synclinal du Horloz, auquel succèdent vers NE l'anticlinal de Bressoux, puis le Synclinal de Wandre.

Le bord S du synclinal de Liège, redressé à la verticale dans l'extrême SW du bassin, est le flanc N d'un anticlinal longitudinal dit de Flémalle, qui s'ennoe et s'atténue vers NE, soit vers l'ombilic du Horloz. Le flanc S de l'anticlinal de Flémalle, distingué souvent comme bassin de Seraing, comporte une suite de plis qui s'extériorisent, au NE de l'anticlinal du Horloz, notamment comme anticlinal de Cointe et, plus au SE, anticlinal de la Chartreuse et se compliquent de chevauchements.

Le bassin de Herve est, au S de ces anticlinaux longitudinaux et à l'E de l'anticlinal de Bressoux, une façon d'expansion méridionale du bassin de Liège. La complication de ses massifs en structure



imbriquée ressort clairement de la coupe verticale transversale ici reproduite. La faille de Saint-Hadelin qui, superficiellement, en constitue la limite méridionale, est un charriage d'importance, comparable à la faille eifélienne, qui limite semblablement le bassin de Seraing, à l'ouest de l'anticlinal transversal de Bressoux.

A présent, voici ce qu'a appris l'exploration paléontologique du "toit" de la veine Desirée-Bouxharмонт.

Dès avant 1830, un Ammonoïdé rangé finalement comme *Gastrioceras* et qualifié d'abord de *listeri*, puis de *carbonarium* ou, enfin, de *subcrenatum*, a été recueilli en divers endroits du bassin de Herve. Les échantillons les plus remarquables sont en ronde bosse et proviennent de nodules calcaireux paniformes, à croûte pyriteuse. La stratification de la masse est nette. A côté de formes adultes, on observe une multitude d'individus plus jeunes, et plus rarement des lamellibranches, des fragments de poissons. Mais hélas! jusqu'ici trop peu de recherches systématiques ont été entreprises pour rechercher dans le détail les variations géographiques de cette faune. Assez récemment, j'ai eu l'occasion, par suite d'une nouvelle recoupe en travers-bancs, de faire quelque récolte à l'extrême SW du bassin de Herve: beaucoup de coquilles de Pélécy-podes (*Myalina* ou *Posidonomya*): nombreuses *Posidoniella laevis*; non moins nombreux Ostracodes et formes naines de Gastéropodes; jusqu'ici pas de Céphalopodes autre qu'*Anthracoceras arcuatilobum*. Associés à toute cette faune, des débris végétaux, souvent très macérés, parfois imprégnés de sulfures ternes (pyrite?): *Aulacopteris*, *Calamites*, *Cordaïtes*, *Sigillaria elegans*.

Dans le bassin de Seraing, à la fosse des Six Bonniers, récemment abandonnée, on a, en divers points, également rencontré depuis 40 ans, un toit de faciès nettement marin, avec *Gastrioceras*, mais sans que, par aucune étude détaillée, il ait été tenté de définir l'extension de ces plages. On est là dans l'extrême prolongement méridional du synclinal du Horloz, mais aussi au voisinage de la faille eifélienne, qui, cisaillant le gisement, ne permet plus d'en connaître l'extension vers le sud.

Au bord nord du bassin de Herve, on a au contraire pu observer nettement la terminaison du faciès à *Gastrioceras*. Il y succède un bande, pas bien large, avec joints couverts d'une forme d'énigmatiques tortillons que Maître Pierre Pruvost a dénommés *Scapellites minor*. Puis, apparaît une flore subautochtone, enfin autochtone, avec nombreux *Calamites* et *Ulodendron lycopodoides* (troncs avec cicatrices raméales, rameaux feuillus, strobiles) et sous-bois (*Pecopteris plumosa*, *Alethopteris* cf. *lonchitica*, etc.). On est là sur le flanc SE de l'anticlinal de la Chartreuse.

Flore similaire, sinon identique, à Ougrée et à Sclessin vers l'extrémité orientale du bassin de Seraing sur le versant SE de l'anticlinal de Cointe et au flanc N de cet anticlinal, à Jupille, où abondent les *Calamites*.

Mais en poursuivant vers NE et en y explorant, grâce à la surélévation, le tréfonds du Synclinal de Liège: rencontre de *Gastrioceras*, puis, peu au NW, sur le versant de ce bassin, d'une bande à *Scapellites minor*, à Trembleur, ou à *Lingula* peu à l'W. Plus au nord encore, à Cheratte, flore subautochtone, puis autochtone avec *Neuropteris schlehani*, *Alethopteris decurrens*, etc., et ainsi jusqu'aux affleurements, à Oupeye, situés en dehors des limites de la coupe horizontale, parce qu'ils sont à une cote de beaucoup supérieure au niveau de celle-ci; tel est également le cas sur la bordure N du bassin de Herve.

Tout à l'extrémité occidentale du bassin de Liège, à la Mallieue (Engis), le dressant de son flanc S a également fourni de nombreux spécimens de *Gastrioceras*, tandis qu'à l'extrémité occidentale du bassin de Seraing, le toit de Désirée n'a fourni que des débris végétaux hachés comme paille au S de l'anticlinal de Flémalle et des buissons de *Calamites* sur son flanc N.

* * * * *

De toute cette recherche, la conclusion pratique est celle qui a été indiquée dans le résumé: Nécessité d'explorations très poussées et, en façon de préparation à cette tâche, mise sur pied d'égalité de la Paléobotanique et de la Paléozoologie dans l'enseignement de la Paléontologie.

Sans doute, les restes animaux sont-ils au moins en apparence d'une étude plus simple pour le débutant; mais les végétaux se présentent bien mieux à une initiation aux divers phénomènes de la

fossilisation, notamment à l'appréciation du caractère d'autochtonie et d'allochtonie; Alfred Nathorst a réclamé avec insistance que l'exploration des gîtes fossilifères soit exécutée et rapportée de manière à définir de façon plus précise cet aspect du faciès. Ce serait un sérieux progrès.

* * * * *

Dans l'exemple brièvement détaillé ci-dessus, on constatera les relations entre faciès et tectonique. C'est l'importance de la subsidence, mettant fin à la formation de la couche de houille, qui détermine les variations de faciès.

L'espace réduit ici imposé ne permet pas d'insister sur ce point, ni sur mille autres détails.

DISCUSSION

P. E. PRUVOST said: Je suis heureux de saisir cette occasion fournie par la très intéressante communication du Professeur A. Renier, pour souligner les récents progrès obtenus, tant dans ce pays grâce aux remarquables études du Dr. A. E. Trueman, que dans l'Europe continentale, en appliquant la notion de faciès, un instant oubliée par les stratigraphes, à l'étude des bassins houillers. Les méthodes de paléontologie stratigraphique ne sont pas absolues. A côté d'elles doivent être employées d'autres méthodes, dont la connaissance et l'utilisation suppose l' "intelligence," comme vient de le rappeler le Dr. Trueman, et c'est grâce à cela que l'on peut espérer arriver à reconstituer l'histoire géologique d'un bassin de sédimentation.

S. VAN DER HEIDE said: Ce qui m'a frappé surtout dans votre conférence c'est que la couche de houille, dont vous avez parlé, est plus épaisse dans les endroits où vous avez trouvé le faciès marin dans le toit de la couche. Je me demande si ce n'est pas le tassement de cette couche, qui a joué le grand rôle. Ce tassement a été beaucoup plus fort dans les endroits où la couche est plus épaisse. Par conséquent la subsidence y doit avoir été plus forte.

A. RENIER in reply said: La puissance d'une couche de houille semble avoir été affectée par le tassement sous la charge des couches surincombantes. Celle-ci pourrait bien avoir été maximum dans les régions de faciès marin, car la puissance de la "stampe" surincombante y est maximum. D'où on conclut que l'accroissement de puissance de la couche de houille doit avoir été originelle et en relation avec le taux de subsidence.

PLANT MICROFOSSIL STUDIES OF EARLY TERTIARY DEPOSITS IN THE WESTERN INTERIOR OF THE UNITED STATES

By L. R. WILSON
U.S.A.

ABSTRACT

The early Tertiary fossil spores and pollen of the Western Interior of the United States have received considerable attention during the last ten years and now may be used to extend and modify earlier palaeontological conclusions arrived at from plant impressions. Coals and shales of Montana and Wyoming contain an abundance of spores and pollen that can be identified with many genera of modern plants. Studies patterned after those of peat investigations have given correlative information concerning the palaeoecology, palaeoclimate, and topography of the Northern Rocky Mountains and the Western Plains.

DISCUSSION

T. M. HARRIS asked whether samples from thin layers show the same general trend or whether they show violent fluctuations.

B. SAHNI considered that some of the spores described by the author were identical with spores, including those of some fungi, from the Tertiary of Assam, and asked whether he had attempted to compare or identify them with living fungus spores.

A. N. THOMAS considered that the local physiographic conditions as deduced from microfossil studies are capable of a different interpretation when applied to regional physiographic history and climate. The change from Lake through Fen and Swamp to Playa could have been achieved by simple sedimentation without uplift. The reverse order of change back to a Lake requires a single gradual subsidence which could possibly be the result of compaction. The climatic significance of the local physiographic conditions can be explained as local microclimates directly dependent on the local physiography and need not have any wider regional significance.

L. R. WILSON, in reply to T. M. Harris, said that he had taken samples as thin as 1 cm. in other instances, although not from the area considered in the paper. The general results they gave were in agreement with those just described. He had not compared the spores with those of modern fungi, as suggested by B. B. Sahni, but he hoped someone would. He agreed with A. N. Thomas that there might be different interpretations from the one that he had advanced, but other regional phenomena harmonised with a history such as he had suggested.

MEGASPORES OF THE TURKISH CARBONIFEROUS AND THEIR STRATIGRAPHICAL VALUE

By S. J. DIJKSTRA

Netherlands

ABSTRACT

From the numerous publications of Zerndt it is evident that Carboniferous megaspores have a great stratigraphical value. A study of the Turkish Carboniferous megaspores has revealed a very sharp boundary between the Aladja-Agzi group (Namurian) and the Kozlu group (Westphalian A). The same result was found in three different sections. Typical megaspores of the Namurian are *Triletes crassiaculeatus*, the megaspore of *Lepidodendron acuminatum*, *T. rotatus*, *T. subpilosus*, and *T. simplex* (respectively type-numbers 26, 19, 27b, 35). Moreover it was possible to subdivide the Namurian into three parts. Typical megaspores of the Westphalian A are *T. mamillarius*, *T. rugosus* and *Cystosporites varius* (respectively type-numbers 14, 25, 30). Besides a great number of seams of the Westphalian A, some samples of the Karadon group (Westphalian D) were studied. Some of its typical spores are *T. glabratus*, *T. tuberculatus*, and *T. tricollinus* (respectively type-numbers 10, 16, 44). Compared with the Polish Carboniferous the vertical distribution of most of the spores is about the same. A remarkable exception is *T. mamillarius*, which occurs in Poland from the Namurian A up to the Westphalian C but which was found in Turkey only in the Westphalian.

I. INTRODUCTION

FROM the numerous publications of Zerndt it is evident that Carboniferous megaspores have a great stratigraphical value. Megaspores are suitable for this purpose, as: (1) their vertical distribution differs; (2) their horizontal distribution is considerable; (3) in contrast with other fossils they are found not only in the slate, but also chiefly in the coal itself; (4) it is possible to macerate them from practically every seam, if the coal has not been coalified too much; (5) as they are very resistant and small it is possible to get good determinable specimens even out of shattered pieces of coal from drilling-samples.

There are three possibilities of using megaspores for stratigraphy: (1) for the rough determination of horizons, (2) for comparing two different coal basins, (3) for detailed zoning, i.e., the study of one definite coal seam over a short distance and its comparison with the seams over and under it. The first two possibilities were used by Zerndt. Besides the Polish coal basin he studied samples of some basins in Germany, France and Bohemia, and compared these with the Polish basin. The rough determination of horizons is very suitable for basins of which the stratigraphy is not known very well. Therefore in Turkey we started with it. Detailed zoning (compare the method of Raistrick) is more suitable for coal seams in a basin which has already been investigated closely. We used it in the study of the Carboniferous of S. Limburg (Dijkstra, 1946).

II. STRATIGRAPHY OF THE TURKISH COAL BASIN

The Carboniferous crops out in a number of places in the northern part of Anatolia near the shore of the Black Sea between Eregli (Heraclea) and Kilimli (east of Zonguldak). More to the east it is found from the environs of Amasra to the river Kidros and beyond.

Ralli (1895-96, 1933) distinguished the following groups: Aladja-Agzi, Kilits*, Cozlou, hiatus, Caradons. He compared it with other basins (see Table I). According to Charles (1933) the Kozlu group belongs to the Westphalian A and B *pro parte*; the Kiliç group is Westphalian A. Hartung (1937) gives another comparison (see Table I).

* The modern spelling is Kiliç.

PART X: FAUNAL AND FLORAL FACIES

TABLE 1

Comparison of the Turkish coal basin with other basins according to

	RALLI		and	HARTUNG
	Basse Silésie Bohême	Heraklée	Heraklea	
Houiller Supérieur	Radowenz			Stefan
Hs	Schadowitz	Caradons	Caradon-Stufe	Westfal D
		lacune	Lücke ?	Westfal C
Houiller Moyen Hm	Couches de Schatzlar	Etage de Coelou	Kochu-Gruppe	Westfal B
		Kilitis	Kilitis-Gruppe	Westfal A
			Flöz Sinork	
Houiller Inférieur	Waldenburg	Aladja-Agzi	Aladscha-Agzi-Stufe Grüne Sandsteine und Schiefer	Namur
Hi	Dachschiefer	Cakaire Vg	Posidonien-Schiefer Kieselschiefer Kohlenkalk	Vise

III. TECHNIQUE

The volatile contents of the Turkish coal are very high: they range from 30-40 per cent, and therefore the coal is very suitable for a study of megaspores. We used Schulze's method, i.e., 10 gm. coal + 10 gm. KClO_3 + 30 cc. HNO_3 (50 per cent) for from one to five days (average three), followed by NaOH (10 per cent) for one day; or Zetzsche's method, i.e., 10 gm. coal + 120 cc. of fuming HNO_3 , with the addition of 3.2 cc. bromine for from four to seven hours (see Dijkstra, 1946).

IV. MEGASPORES OF THE TURKISH CARBONIFEROUS

The following spores have been found in the Turkish Carboniferous. Most of them are described by Zerndt, while a review of them can be found in Dijkstra & van Vierssen Trip (1946).

Type 1(29). *Cystosporites giganteus* (Zerndt), both fertile and sterile specimens.

2. Calamariaceae spores, generally a little bigger than those from South Limburg.

10. *Triletes glabratus* Zerndt.

11. *T. auritus* Zerndt, only specimens with small ears.

13. *T. hirsutus* (Loose).

13a. *T. hirsutus* (Loose) var. *brevispinosa* Zerndt. The most important difference between type 13 and 13a is that the contact faces of 13a have four to five arched folds, the curvature of which is turned towards the nozzle. Zerndt (1937) divides the variety *brevispinosa* into two forms—forma I covered with short appendages 6 μ long, and forma II covered with appendages 36-96 μ long. The difference between *T. hirsutus* and *T. hirsutus* var. *brevispinosa* forma II is not very considerable and it is sometimes difficult to distinguish them.

14. *T. mamillarius* Bartlett.

16. *T. tuberculatus* Zerndt.
17. *T. triangulatus* Zerndt.
19. *T. rotatus* Bartlett.
20. *T. brasserti* Stack & Zerndt.
- 20a*. *T. brasserti* Stack & Zerndt forma *minor* Dijkstra.
21. *T. praetextus* Zerndt.
- 21a*. *T. praetextus* Zerndt forma *minor* Dijkstra.
25. *T. rugosus* (Loose) Dijkstra; specimens with a smooth, thin spore-coat, and others with a thick, punctate spore-coat. The first are mature spores, the last immature specimens.
26. *T. crassiaculeatus* (Zerndt). Professor Jongmans found in the roof of a certain seam many specimens of only *Lepidodendron acuminatum* Goepf. and a great number of megaspores. These megaspores appeared to be *T. crassiaculeatus*, which have been found moreover in great numbers in the seam itself. The vertical distribution of *L. acuminatum* and *T. crassiaculeatus* is the same. According to us *T. crassiaculeatus* is the megaspore of *L. acuminatum*.
- 27a. *T. horridus* (Zerndt).
- 27b. *T. subpilosus* (Ibrahim) forma *major* Dijkstra.
29. *Cystosporites giganteus* (Zerndt) forma *sterilis*.
30. *C. varius* (Wicher), sterile and fertile specimens.
31. *Monoletes* Ibrahim.
35. *T. simplex* Zerndt.
36. *T. simplex* (Zerndt) var. *levis* Zerndt; according to us the sterile or immature spore of *T. simplex*; they are found together in samples, and are sometimes difficult to distinguish from each other.
37. *T. dentatus* Zerndt.
44. *T. tricollinus* Zerndt.
49. *Microsporites karczewskii* (Zerndt).
- 51*. *T. anatolicus* Dijkstra [see Dijkstra, 1952, p. 102.]
- 52*. *T. eregliensis* Dijkstra [see Dijkstra, 1952, p. 102.]

V. SPORE-CONTENT OF THE ALADJA-AGZI GROUP AND ITS DIFFERENCE FROM THAT OF THE KOZLU GROUP

To get an idea of the spores occurring in the Aladja-Agzi and the Kozlu groups some samples of these groups have been studied first. In the Aladja-Agzi group types 1 (29), 13a, 17, 20a, 21a, 26, 27b, 35, 36, 49 were found; in the Kozlu group types 1 (29), 2, 13, 14, 17, 20, 21, 25, 30, 49. Later on still more types were found in both groups. In the second place it was important to test the possibility of drawing a sharp line with the help of spores between these two groups. Of course it was possible that a transition zone would be found between them. Therefore all the coal seams and brats of the Aladja-Agzi group were studied in three different profiles, beginning with the undermost seam of the Aladja-Agzi group and ending somewhere in the Kozlu group. These profiles are situated in the Asma valley, the Kokakou valley, and the Kilic valley. According to us it is possible to draw in all three profiles a sharp boundary between the Aladja-Agzi and the Kozlu groups. A more detailed review follows, and moreover we shall try to subdivide the Aladja-Agzi group. For this a complete profile is necessary: I believe the most complete one is that of Asma, with which we shall therefore start. Types 1 (29) and 49 are very unimportant for this purpose, because they are found in nearly every sample of the Turkish Carboniferous.

In the oldest (about 17) seams to the right of the river are found types 1 (29), 20a, 26, 27b, 49; 21a in two samples; 13a forma I and 19 in one sample.

* These numbers are introduced by me and are not Zerndt's.

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In the next 11 seams to the left of the river the same types occur, but the percentage of 26 has decreased, 13a forma I has increased, and moreover 35 and 51 are found.

The 13 highest seams do not contain types 13a forma I and 26; 13a forma II and 17 have been noticed, and 19 has increased.

The last four to five seams of this profile contain only types 1 (29), 14, 17, 21, 25. Then follows the Faille du Midi; on the other side of this fault seams occur that contain the same types as were found in the last four to five seams mentioned.

The Kokaksu profile shows the same succession. The lowest seams contain mainly types 1 (29), 20a, 26, 27b, 49. In the next ones type 26 decreases, 13a forma I increases, 35 (36) is present. Then follows the Faille du Midi. This fault must have cut off the highest seams of the Aladja-Agzi group. In this way we can explain why 13a forma II, 19, and 51 have not been found here. After the fault 16 seams and brats of the Kozlu group have been studied; they contain types 1 (29), 2, 13, 14, 17, 20, 21, 25, 30, 31, and 49. More to the north the big seam Çay occurs, but this has not been studied.

In the Kiliç valley we found exactly the same subdivisions as noticed at Asma, but the highest beds of the Aladja-Agzi group found there are succeeded by four to five seams which also belong to the lowest part of the Aladja-Agzi group, because they contain type 26 while the types of the highest part of the Aladja-Agzi are lacking. In the direct neighbourhood of these seams at a distance of some metres the Büyük Kiliç Seam, which belongs to the Kiliç group, has been found, succeeded by a series of seams also belonging to the Kiliç group. The seams of this group contain the spore-types 1 (29), 2, 13, 14, 17, 20, 21, 25, 30, 49. Our conclusion is that a fault between these four to five seams and the Büyük Kiliç Seam must exist, and this agrees with Zeiller who came to the same conclusion. According to Ralli the Büyük Kiliç Seam belongs to the Kiliç group; in the neighbourhood he found Culm in concordance with the Kiliç group. Dr. Zijlstra (by letter) confirmed our opinion that a fault had been found exactly where we expected it.

Finally we studied some seams at Armutçuk, where again a sharp boundary between the Aladja-Agzi and the Kiliç groups was found.

VI. THE KOZLU AND THE KILIÇ GROUPS

Besides about 25 seams sampled on the surface in the valleys mentioned already, some seams of these groups that were sampled in mines were studied. For want of time it was not possible to study them all, and therefore some seams of the top, of the middle, and of the base of the Kozlu group at Kozlu were taken. They are the Papas, Kesmeli, Istefan, Acenta, Lukiça, Leonidas, Hacı-Petro, and Kürtşerif seams, and, of the Kiliç group, the Topus, Omer ağa, Civelek, Küçük, x1, x2, x3 seams (Büyük Kiliç was sampled on the surface). Their spore-contents have already been mentioned. Type 2 and especially type 17, which are very rare in the Aladja-Agzi group, are common in the Kozlu- Kiliç group. Type 31 was found in one sample only. One seam of the lowest part of the Kozlu group at Asma moreover contained some specimens of type 51. It was not possible to notice any difference in spore-contents between the lowest part and the highest part of the Kozlu group, neither between the Kozlu and the Kiliç groups.

VII. THE KARADON GROUP

It was not possible to make such a detailed study of the Karadon group as was made of the Aladja-Agzi group, because the Karadon group is less well known, and moreover the time was too short to do so.

At Ökusne, Kozlu, 9 seams were studied, beginning with the highest seam, which is at the base of the Red Series. The types found were 1 (29), 10, 11, 14 (in one sample only), 16, 17, 20.

At Kiliç Mahallesi 8 seams gave the same types, except type 14; in addition 25, 30, 31, 44, 49, 52.

At Illiksu 3 seams gave: 1 (29), 10, 14, 16, 17, 20, 25, 30, 31, 37, 49.

At Kireçlik 1 seam gave: 1 (29), 14, 16 (one specimen), 17, 20, 25, 30.

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Compared with the Kozlu group types 2, 13, 21, 51 were not found, but on the other hand types 10, 11, 16, 37, 44, 52 occur and type 31 is more frequent.

VIII. WESTPHALIAN B?

Zeiller and Ralli assumed a stratigraphical hiatus between the Kozlu and the Karadon groups. They believe that this hiatus has been filled up by a conglomerate (Cg2), or that during that period there was a pause in sedimentation. The apparent presence of a hiatus may be explained by big faults or by incomplete study material.

Some seams at Kozlu which according to Dr. Egemen belong to the Westphalian B may perhaps be considered as a link between the Kozlu and Karadon groups. Six seams have been investigated, and the following types have been found: 1 (29), 14, 17, 20, 21, 25, 31, 49. As the coal was very weathered and dirty, and many spores were broken, it was difficult to determine them, so that still more types may be expected.

IX. DISCUSSION

A typical spore of the lowest part of the Aladja-Agzi group is *T. crassiaculeatus*, type 26; it was found by Zerndt in the lowest "Randschichten" of Poland, Namurian A or Dinantian. The part of the Aladja-Agzi group that contains many specimens of this spore is Namurian A.

TABLE II

Distribution of megaspores in the Turkish Carboniferous in comparison with Poland.

Type	Turkey					Dinantian	Poland				Type				
	Namurian			Westphalian			Namurian			Westphalian					
	A	B	C	A	B	C	D	E	A	B	C	A	B	C	D
1 (29)
2
10			
11			
12				.								.			
13				.					(?)			.	.		
13a I	.	.													
13a II			.							.	.				
14				.	.		.		(?)
16			
17
19	(?)			
20					
20a*		
21					
21a*		
24				.			.					.			
25					
26		
27a		
27b		
30				.	.		.					(?)	.	.	.
31			
35 (36)			(?)	(?)	.	.		
37					
44					
49		(?)	(?)	.	.	(?)	(?)	(?)
51*		
52*					

* These numbers are introduced by me and are not Zerndt's.

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In the middle part of this group *T. simplex*, type 35 (36), is found which occurs in Poland in the Namurian B (?), A (?). The spore *T. anatolicus*, type 51, occurs in this part too. It is Namurian B.

In the upper part of the Aladja-Agzi group *T. hirsutus* var. *brevispinosa* forma II is important; *T. rotatus*, type 19, is more frequent; *T. crassiaculeatus* and *T. hirsutus* var. *brevispinosa* forma I do not occur. This part is Namurian C.

A typical spore of the whole Namurian is *T. subpilosus* forma major, type 27b.

In the Kozlu-Kiliç group *T. mamillarius*, *T. rugosus* and *Cystosporites varius*, types 14, 25 and 30 respectively, have stratigraphical value. *T. rugosus* is found in the Polish Carboniferous in the Westphalian A and B; *Cyst. varius* in the Westphalian D, C and B, and probably in A. *Triletes mamillarius* has probably only local stratigraphical value. In Turkey this type has not been found in the Aladja-Agzi group, but nearly every seam of the Kozlu-Kiliç group contains it. In Poland *T. mamillarius* has been found from the Namurian A up to the Westphalian C. This type must be composed of megaspores coming from a number of different plants. As mentioned already the spore-contents of the Kozlu group and the Kiliç group at Kozlu are the same; both belong to the Westphalian A. It was not possible to decide by means of spores which group is the oldest. According to Ralli the Kiliç group is the lowest and his table I shows it as belonging partly to the "Houiller Inférieur," partly to the "Houiller Moyen," but in the text he does not indicate which seams belong to the first group and which to the second one. Ralli has distinguished the Kiliç group from the Kozlu group, because he found less plant fossils in it than in the Kozlu group, but it is very difficult to collect good determinable plant fossils (except spores) in these vertical seams. Moreover not every seam in the Kiliç valley belongs to the Kiliç group. The name Kiliç group is confusing. Perhaps it is better to cancel this name.

A typical spore of the Karadon group is *T. tuberculatus*, type 16, found in nearly every sample. Its occurrence in Poland is in the Westphalian D and upper part of C. Other spores which have great stratigraphical value are *T. tricollinus*, type 44, and *T. glabratus*, type 10; their occurrences in Poland are Westphalian D, C and B. Moreover *T. auritus*, type 11, is found in Poland in the Westphalian D, C and B, and *T. dentatus*, type 37, occurs in Poland in the Westphalian D and C (upper part). Our conclusion is that the youngest of the studied seams of the Karadon group belong to the Westphalian D, and the oldest of this series to the Westphalian D or perhaps to the upper part of the Westphalian C.

In comparison with the Polish Carboniferous some types which occur there in the Dinantian, Namurian and Westphalian A (?) were not found in Turkey. In general they are rare types, noticed in very few samples. In the Westphalian B, which was studied only partially, and in C, which was not studied at all, we may expect *T. appendiculatus*, type 12, and *T. superbus**, type 24. All the spores of the Westphalian D which have been found in Poland occur in Turkey too. In the Westphalian E we may expect new types. Later we hope to have the opportunity to complete these hiatuses.

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* Dr. Zijlstra kindly sent me in 1950 a coal sample from the Westphalian C of Turkey which contains *T. superbus* among other spore-species.

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DISCUSSION

B. SAHNI commented on the large size of one of the megaspores described, and asked about the limits of size of Carboniferous megaspores.

T. F. GRIMSDALE asked if the megaspores are visible in the rocks before the treatment by maceration, or whether maceration is essential before the spores become visible.

W. J. JONGMANS referred to the difficulties in comparing the stratigraphy of different coal basins because of their very different developments. It is possible to use marine bands as datum planes in W. Europe and in some other parts of the world. But they cannot be used in those basins where they are absent. This is the case in Turkey where marine bands are present only in the lowest part. So we have to use other methods, both floral and faunal. He and Dr. Egemen had tried to make floral zones with rather good results. However, the study of the megaspores has been very useful. Because of the high percentage of volatile matter, over 20 per cent in all the seams, it is possible to macerate the spores from them and to tabulate the distribution of the different types in seams from the lowest Namurian to a high level of the Upper Carboniferous. It had been proved that every group has its typical spores, so that their study provides an excellent method of comparing the different basins.

It is peculiar, as Harris had shown in his studies on Rhaetic and Jurassic floras, that the number of types of spores is much larger than that of lycopods present in impressions. The same is true in Turkey. This is especially clear in the lower parts, where there are only a few lycopods as impressions but numerous spores. It is clear, therefore, that the study of megaspores in the Carboniferous and in the Mesozoic can contribute much to our knowledge of the lycopods, especially of the arborescent forms.

S. J. DIJKSTRA, in reply, said that the size of the Carboniferous megaspores varies from about 400–3,000 μ . The biggest spores belong to the genus *Cystosporites* and are 3–11 mm. in size. It is possible to find megaspores in the slate, but most of them occur in the coal and must be macerated out of it. He agreed with W. J. Jongmans that it is very remarkable that the number of types of megaspores found in the Namurian is much larger than the number of lycopod species known in this series. The same was found by T. M. Harris in the flora of Scoresby Sound, East Greenland.

CORRELATION OF THE LOWER BROWN LIMESTONE OF NORTH WALES WITH PART OF THE LOWER CARBONIFEROUS SUCCESSION IN SCOTLAND AND NORTHERN ENGLAND

By W. S. LACEY
Great Britain

ABSTRACT

The Lower Carboniferous in North Wales consists of limestones and subsidiary rocks totalling over 3,000 feet in thickness and falls within the Dibunophyllum Zone of the Bristol sequence.

In the older lithological classification plant remains occur at two horizons:—

- (1) near the base of the Upper Black Limestone, near Prestatyn, Flintshire (P);
- (2) in the lower beds of the Lower Brown Limestone in Flintshire and Denbighshire, and in Basement Beds of similar age in Caernarvonshire (D1).

The Upper Black Limestone flora has been described by Walton (1926–31) and the beds correlated with the *upper part* of the Scottish Oil Shale Group.

The results so far obtained from the detailed study of the Lower Brown Limestone flora now in progress do not support the suggestion made by Walton (1931) that the *Archaeosigillaria* horizon appears to indicate a position very near the base of the British Lower Carboniferous succession, but suggest the correlation of the Lower Brown Limestone with the *lowest part* of the Scottish Oil Shales and equivalent beds in Northern England. These conclusions receive faunal support.

I. INTRODUCTION

THE Lower Carboniferous Succession in North Wales consists largely of a series of limestones which are underlain by Basement Beds resting unconformably on the Silurian and followed by cherts, shales and sandstones. These rocks together reach a maximum thickness of over 3,000 feet and their outcrop extends practically continuously for nearly a hundred miles from the South-west of Anglesey in the west to Llanymynech in the east.

Both in Anglesey (Greenly, 1919) and on the mainland (Hind & Stobbs, 1906; Greenly, 1928; Neaverson, 1946) these Carboniferous Limestone strata have been classified by their faunal remains,

TABLE I

Subdivision of the Carboniferous Limestone in North Wales		
<i>Morton's subdivisions</i>	<i>Current nomenclature</i> (Smith & George, 1948)	<i>Faunal Sub-Zones</i>
(4) Upper Black Limestone (North Flintshire)	Black Limestone	P, but regarded as an argillaceous phase of D2 by Neaverson (1945, 1946)
Sandy Limestone (S. Flintshire and Denbighshire)	Sandy Limestone Group	
	? Cherts and thin limestones in Anglesey, Greenly (1919)	
(3) Upper Grey Limestone	Upper Grey Limestone	D2
	Purple Sandstone in parts of the Vale of Clwyd—Neaverson (1946)	
(2) Middle White Limestone	Middle White Limestone	D1
(1) Lower Brown Limestone with Basement Beds	Lower Grey and Brown Limestone with Basement Beds	D1 (some S2 species recorded near the base of the limestone) ? S2, but regarded as D1 by Neaverson (1945)

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especially corals and brachiopods, and have been shown to fall wholly, or almost wholly, within the Dibunophyllum Zone, the uppermost division of Vaughan's classification of the Lower Carboniferous succession as worked out in the Bristol area (1905). The earlier classification of the Carboniferous Limestone by Morton (1870-1901), based largely on lithological differences, is, however, still in common use (Smith & George, 1948, for example), and taken in conjunction with modern terms provides a convenient scheme of subdivision for use in the present paper.

Morton divided the limestone into four main groups which are listed together with current nomenclature and equivalent faunal zones in Table I.

Well-preserved plant-remains, drifted from nearby land, are known at two horizons, namely, (1) near the base of the Upper Black Limestone at Teilia, Gwaenysgor, near Prestatyn, North Flintshire, and (2) in the lower beds of the Lower Brown Limestone at several localities in the Vale of Clwyd and in Basement Beds of similar age in Caernarvonshire.

(1) The fossil flora of the Upper Black Limestone has been described by Kidston (1889), Walton (1926, 1928, 1931), and Benson (1935), while the correlation of these beds with the Lower Carboniferous of other areas in Britain and on the continent has been effected by Walton (1928, 1931) on the evidence of both the floral and the faunal content.

(2) The plant-remains occurring in the Lower Brown Limestone are not so well-preserved nor as numerous in species as those in the Black Limestone, and no detailed study of the flora of the Lower Brown Limestone has been attempted hitherto. As long ago as 1925 Jackson pointed out the necessity for further work on the fossil animals and plants to determine the correlation of these beds with the Lower Carboniferous succession of Scotland.

A detailed study of the flora of the Lower Brown Limestone in North Wales is now being undertaken by the writer and, though this work is not yet complete, the plants collected and identified during the last three years, together with the evidence of faunal remains, provide information upon which tentative correlations may be based.

II. THE FOSSIL FLORA OF THE LOWER BROWN LIMESTONE

Plants have been collected from the Lower Brown Limestone at three localities in the Vale of Clwyd, namely, near Dyserth, Denbigh, and Nantclwyd, a few miles south of Ruthin; and from Basement Beds of similar age in the Menaian region of Caernarvonshire.

For the purposes of subsequent correlation and discussion it is important to know as nearly as possible the age of this flora. There is no doubt that the plants occur low down in the Lower Brown Limestone, and at Dyserth, in particular, the plant-bearing shales lie only a few yards above the red Basement Beds. These Basement Beds were formerly assigned by Neaverson (1930) to the top of Vaughan's *Seminula* Zone (S2) on stratigraphical grounds alone, since no indigenous fossils of correlative value have been found. It should also be noted that in the overlying Lower Brown Limestone a few faunal remains suggestive of the S2 sub-zone have been found near the base of the limestone in certain localities (Wedd & others, 1924, 1927). It may be added that Cope (1940) regards *Daviesiella llangollensis* (Dav.), which occurs at all three localities in the Vale of Clwyd mentioned above, as indicating a S2-D1 age, and further suggests that "the bottom beds of the Lower Brown Limestone—are probably of S2 age" (p. 212).

Subsequently, however, Neaverson (1945) stated that it seems certain that the Red Basement Beds should be included within the D1 sub-zone and that there is no justification for relegating the Brown Limestone to the S2 sub-zone. Whichever view should prove to be correct, the floral assemblage of the Lower Brown Limestone can be regarded, for the purposes of correlation, as being of S2-D1 age, that is, as indicating the top of the S2 sub-zone and the base of the D1 sub-zone.

A considerable quantity of material has been collected during the last three years from the localities mentioned. Some of it awaits further study, but the list of plants so far obtained is given in Table II, together with an indication of the occurrence of these plants in other areas. Information on the

PART X: FAUNAL AND FLORAL FACIES

distribution outside North Wales has been obtained from Kidston (1893, 1901), Crookall (1932) and Walton, Weir & Leitch (1938).

TABLE II

List of Plants from the Lower Brown Limestone in North Wales with their distribution in Scotland and Northern England

List of Plants	Lower Brown Limestone	Oil Shale Group (or equivalent beds)	Cementstone Group (or equivalent beds)
1. <i>Bythotrephes plumosa</i> Kidst.	cf.	X	
2. <i>Archaeosigillaria vanuxemi</i> (Goepp.) Kidst.	X		X
3. <i>Lepidodendron</i> sp.	X	X	X
4. <i>Lepidodendron volkmannianum</i> Sternbg.	cf.	X	
5. <i>Lepidostrobus fimbriatus</i> Kidst.	X	X	X
6. <i>Knorria</i> sp.	X		
7. <i>Stigmaria ficoides</i> Sternbg.	X	X	X
8. <i>Asterocalamites</i> (<i>Archaeocalamites</i>) <i>scrobiculatus</i> Schloth.	X	X	X
9. <i>Rhodea</i> sp.	X	Species recorded	Species recorded
10. <i>Rhacopteris Weissii</i> Walt.	X		
11. <i>Rhacopteris subcuneata</i> Kidst.	X	X	
12. <i>Rhacopteris</i> sp.	X	Species recorded	Species recorded
13. <i>Telangium affine</i> Kidst.	cf. (rachis only)	X	
14. <i>Calathiops</i> sp.	X		Species recorded
15. Seed-like bodies	X	Species recorded	Species recorded
16. Lycopodiaceous megaspores	X	X	X
17. Microspores of several kinds	X	X	X

The distribution of some of the plants listed above needs further explanation.

(1) *Bythotrephes plumosa* (which was regarded as an alga by Kidston) is recorded from the Oil Shale Group of Glencartholm, Eskdale, and from near the base of the Fell Sandstone in Cumberland. Kidston (1925) included the Fell Sandstone in the Cementstone Group, but Macgregor & MacGregor (1948) place these beds at the base of the Oil Shale Group.

(2) *Archaeosigillaria vanuxemi* is not recorded from Scotland but from beds in the North-west of England (Westmorland) which are indicated as being *approximately* the equivalent of the Cementstone Group in Scotland (see Kidston, 1893, p. 224, in conjunction with 1901, p. 38, and Jackson, 1910). Garwood (1912) regards this Westmorland horizon as not later than sub-zone C2, while Pringle (1948) assigns a C1-C2 age to the Cementstones of Liddesdale.

The statement made by Jackson (1925) that "*Archaeosigillaria* (as *Lycopodites*) *vanuxemi* is recorded by Dr. Kidston from the Cementstone Group of Scotland" is evidently a misinterpretation, for Kidston does not make any special reference to its occurrence in Scotland—see also Walton (1931, p. 372) in this connection. It is rather surprising that *Archaeosigillaria vanuxemi* has not so far been found in Scotland. The occurrence at Glencartholm of two of its associates in the Lower Brown Limestone at Dyserth, namely, *Bythotrephes plumosa* and *Lepidostrobus fimbriatus*, is suggestive.

(3) According to Walton, Weir & Leitch (1938) *Lepidostrobus fimbriatus* has been recorded more frequently from the Cementstone Group of Scotland than from the Oil Shale Group. When, however, the records from the North of England (Cumberland and Northumberland) are included the reverse is the case, and there are some twelve or fifteen records from the *lowest beds* of the Oil Shale Group as against six or seven from the Cementstone Group.

(4) *Asterocalamites* (*Archaeocalamites*) *scrobiculatus* is recorded from all divisions of the Lower Carboniferous in Scotland and would thus appear at first sight to have little value in correlation. It should be noted, however, that more than 60 per cent of the localities from which it is recorded in Scotland are in the Oil Shale Group (Walton, 1931, p. 369), and it is also recorded from equivalent beds in Northumberland and Durham.

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(5) *Rhacopteris subcuneata* is not recorded from Scotland but from Northumberland in beds *low down* in the Carbonaceous Group (= Scremerston Series, correlated with the lower division of the Oil Shale Group, below the Burdiehouse Limestone, in Central Scotland). A number of other species of *Rhacopteris* have been recorded from the Calciferous Sandstone Series of Scotland, and the records appear to indicate that *Rhacopteris* species are more common in the Oil Shale Group.

(6) Certain of the plants listed in Table II have little or no value in correlation. Thus *Stigmaria ficoides* and species of *Knorria* are non-zonal fossils, while no useful comparisons can be made in those cases where the species is as yet undetermined. It may be stated, however, that more species of *Rhodea* have been recorded from the Oil Shale Group than from the Cementstone Group in Scotland, while two species of *Telangium* (*affine* and *bifida*, now included in *Sphenopteris*—see Crookall, 1932) are characteristic of the Oil Shale Group.

(7) The structure of the seed-like bodies, recently discovered in the Basement Beds in Caernarvonshire, is not yet sufficiently well known to make possible a comparison with seeds recorded from the Calciferous Sandstone Series elsewhere.

(8) The same type of difficulty arises with regard to the spore content of the various beds. Though megaspores and microspores are known from the various divisions of the Calciferous Sandstone Series, as also from the Lower Brown Limestone in Wales, too little is known of the microflora to make comparisons possible.

The detailed study of the spore content, on the lines of that being undertaken by Mrs. E. M. Knox on the Limestone Coals of Scotland, is a possible source of further information which may prove of value in correlation.

III. THE FOSSIL FAUNA OF THE LOWER BROWN LIMESTONE

The lists given in Table III include most of the animal remains occurring in the Lower Brown Limestone of North Wales. They have been obtained from Neaverson (1930, 1945) with additions from the writer's collecting.

TABLE III

The Fauna of the Lower Brown Limestone

(1) DYSERTH

Zaphrentis spp.
Palaeosmilia murchisoni E. & H.
Lithostrotion cf. *irregulare* (Phill.)
Lithostrotion sp. (Clisiophylloid form)
Lophophyllum cf. *ashfelliense* Garwood
Syringopora cf. *gigantea* Thomson
Athyris expansa Phill.
Athyris glabistria Phill.
Composita cf. *ficoidea* (Vaughan)
Spirifer sp.
Daviesiella llangollensis (Dav.)
Productus cf. *hemisphericus* J. Sow.
Aviculopecten cf. *eskdalensis* Hind
Straparollus dionysii (Mont.)
Conularia tenuis var. *maculosa* Slater
Spirorbis sp. (impressions)
 Ostracod remains

(2) DENBIGH

Lithostrotion cf. *martini* E. & H.
Lithostrotion irregulare (Phill.)
Syringopora geniculata Phill.

DENBIGH (continued)

Overtonia fimbriata (J. de C. Sow.)
Productus cf. *hemisphericus* J. Sow.
Productus cf. *semireticulatus* Mart.
Productus margaritaceus Phill.
 Spinous Productid (*Pustula* group)
Spirifer sp.
Daviesiella llangollensis (Dav.)
Schellwienella crenistria (Phillips) (North of Denbigh)
Euomphalus cf. *pentagulatus* Sow.
Endothyra sp.
Fenestella sp.
 Ostracods
 Crinoid detritus

(3) NANTCLWYD

Daviesiella llangollensis (Dav.)
Productus sp.
Euomphalus sp.
Bellerophon sp.
 ? *Spirorbis*
Cytherella sp.

PART X: FAUNAL AND FLORAL FACIES

IV. CORRELATION OF THE LOWER BROWN LIMESTONE WITH PART OF THE LOWER CARBONIFEROUS SUCCESSION IN SCOTLAND AND NORTHERN ENGLAND

On the basis of the fossil flora the Lower Brown Limestone in North Wales can clearly be correlated with a part of the Calciferous Sandstone Series of Scotland and equivalent beds in the North of England. The question as to which part presents more difficulty.

Walton (1928, 1931) has already correlated the Upper Black Limestone at Teilia, some 2,000 feet above the Lower Brown Limestone, with the *upper part* of the Oil Shale Group at about the horizon of the Blackbyre Limestone in Central Scotland. This conclusion receives faunal support, in particular from the occurrence of *Posidonia* (*Posidonomya*) *becheri* in the beds correlated.

The correlation of lower limestones in the North Wales sequence is on less firm ground. The Middle White Limestone is shown by Walton (1931, Table II, p. 373) as equivalent to the Cementstone Group in the Calciferous Sandstone Series of Central Scotland, although no direct evidence is put forward in the text in support of this correlation. It would appear to have been based largely on the occurrence of *Archaeosigillaria vanuxemi* at all the plant-yielding localities in the Lower Brown Limestone of the Vale of Clwyd. Outside Britain this species has been recorded from the base of the Visean in France, the Lower Carboniferous of Spitzbergen, the Upper Devonian of New York State, and the Upper Devonian of Belgium (references for these records will be found in Walton, 1931). These facts led Walton to state in 1931 (p. 374) that "the *Archaeosigillaria* horizon would appear to indicate a position very near the base of the Lower Carboniferous in Britain."

This view and the consequent correlation of the Middle White Limestone with the Cementstone Group of Scotland can no longer be held, since subsequently Neaverson (1945) has assigned a D1 age to the Lower Brown and Middle White Limestones, while Macgregor (1930), Macgregor & MacGregor (1948), and Pringle (1948) have assigned a C1-C2 age to the Cementstone Group. The occurrence of *Archaeosigillaria vanuxemi* in the D1 sub-zone of the Visean, which is itself the upper part of the complete Lower Carboniferous Succession (Avonian) in Britain, and even the Westmorland records which are referred to beds not later than sub-zone C2, can hardly be regarded as indicating "the base of the Lower Carboniferous in Britain." Neaverson (1945) does not even agree that the occurrence of *Archaeosigillaria vanuxemi* necessarily indicates the base of the Lower Carboniferous in Wales!

The evidence presented by the fossil plants so far collected from the Lower Brown Limestone is not unequivocal, but it strongly suggests to the writer that, despite Walton's suggested correlation of the Middle White Limestone with the Cementstone Group of Scotland and the stress laid on the occurrence of *Archaeosigillaria vanuxemi* in the Lower Brown Limestone of North Wales, these latter beds should be correlated with *lowest part of the Oil Shale Group* in Scotland and with equivalent beds in the North of England. This general correlation can be narrowed down with some degree of probability:—

(1) Central Scotland (Midlothian). Below the Burdiehouse Limestone and above the Granton and Craigmyle Sandstones, very probably about the horizon of the Wardie Shales.

(2) South of Scotland (Eskdale and Liddesdale). At about the junction of the Lawston Linn and Muirburn Coals with the Glencartholm Volcanic Group, or perhaps with the Glencartholm Volcanic Group.

(3) North of England (Northumberland). At about the base of the Scremerston Coal Group and above the Fell Sandstones.

This suggested correlation receives a certain amount of faunal support.

From the faunal lists given in Table III the following species may be particularly noted:—

(1) *Athyris glabistria* has been recorded from the top of the Cementstone Group in South Scotland (Eskdale and Liddesdale) to which a C2 age has been assigned (Pringle, 1948).

(2) *Conularia tenuis* var. *maculosa* Slater has only been recorded elsewhere from the Calciferous Sandstone Series of Glencartholm, Eskdale, and Woodhall Mill, Water of Leith, Edinburgh, at an

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horizon "probably near the base of the Wardie Shales and above the sandstones of Craighleith and Granton" (Jackson, 1925).

(3) *Aviculopecten* cf. *eskdalensis*, found at Dyserth, resembles *A. eskdalensis*, another Glencartholm species from an horizon low down in the Oil Shale Group.

(4) *Lithostrotion* spp. (including clisiophylloid forms). It is interesting to note that species of *Clisiophyllum* and *Lithostrotion* have been recorded from the Lawston Linn Coal Group of South Scotland (Pringle, 1948), and that clisiophylloid forms of *Lithostrotion* are known from Northumberland (Neaverson, 1930).

(5) *Daviesiella llangollensis*, regarded by Cope (1940) as confined to beds of S2-D1 age, has been recorded from Kirkby Stephen, Westmorland, but so far this is the most northerly record available.

(6) *Overtonia fimbriata* and (7) *Schellwienella crenistria* have been recorded from the Lower Limestone Group (D2) which overlies the Oil Shale Group in Scotland (Macgregor, 1930).

V. SUMMARY AND CONCLUSION

(1) The lycopodiaceous plant *Archaeosigillaria vanuxemi* (Goeppert) Kidston has a wide vertical range from the Upper Devonian to the Upper Visean and is thus of little or no value in correlation.

(2) On the basis of the fossil flora the Lower Brown Limestone of North Wales is correlated with the lowest part of the Oil Shale Group in Scotland and with equivalent beds in the North of England.

(3) This correlation receives a certain amount of faunal corroboration.

(4) From the correlation suggested above, a S2-D1 age is indicated for the lowest part of the Oil Shale Group in Scotland and equivalent beds in Northern England. This confirms the suggestion made by Macgregor (1930, p. 476) that the lower part of the Oil Shale Group in Scotland and the Scremerston Coal Group in Northumberland are "probably equivalent to the greater part, if not all, of the *Seminula* Zone (S) and the lower portion of the Lower *Dibunophyllum* Zone (D1)." Since a C1-C2 age has already been assigned to the Cementstone Group (Macgregor, 1930; Eastwood, 1946; Pringle, 1948), a C2 age to the Fell Sandstone Group (Macgregor, 1930; Eastwood, 1946; Pringle, 1948), and D2 and D3 ages to the upper part of the Oil Shale Group and succeeding Carboniferous Limestone Series, the zoning of the Scottish and Northern English Lower Carboniferous in terms of the Bristol sequence is now almost complete. It is possible that the S1 sub-zone is represented at the top of the Fell Sandstone.

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DISCUSSION

T. N. GEORGE maintained that the age of the lowest Avonian strata of North Wales is not precisely determinable by their fossils because the sub- D_1 succession in the type Avon section is of different facies. *Daviesiella*, represented in the South-Western Province typically by *Daviesiella comoides* which ranges up to the top of D_2 , is not a satisfactory basis for dating D_1 ; and the athyrids referred by Neaveyson to *Composita* are certainly not conspecific with Vaughan's *ficoidea*, and may not even belong to the genus. *Archaeosigillaria vanuxemi*, a repository for a variety of homoeomorphs, is a 'species' too long-ranging to be of use in zonal identification: reputedly it extends beyond the limits of the Avonian series, and certainly has been recorded from the Lower Avonian.

The Basement Beds of North Wales are in all probability diachronic, in the manner typical of rudaceous sediments displaying gross overstep. Their age is unknown, and their apparent association with the overlying D_1 Lower Brown Limestone may be deceptive, especially where there is an abrupt junction. In places they contain fine-ribbed chonetids and a small rhynchonelloid superficially like *Camarotoechia mitcheldeanensis* which suggest a Lower Avonian age.

The extension at second remove of Avonian correlation to Scotland, where no zones below D_2 have yet been recognized with certainty, is precarious. Occasional shell-beds in the upper part of the Oil Shales of Fife have yielded goniatites referred to *Beyrichoceratoides cf. truncatum*, which may justify their being placed in the P_1 Zone, deviously correlated via the Midland Province with the D_1 - D_2 Zone. But no usable fossils occur at lower horizons until the Randerstone shell-beds of the Fife Cementstones are met: these contain small rhynchonelloids said to be identical with *Camarotoechia proava*, and on that tenuous thread may be hung correlation with the *proava*-beds of Cumberland and Westmorland, which in their turn have been allocated, on not very strong evidence, to the C_1 Zone. If there are no gaps in the Scottish succession, it may therefore be the case that the Oil Shales span several zones, and in large part may not be represented by equivalent sediments in North Wales.

B. SAHNI asked whether the age as given by the plants agreed with that deduced from the animals.

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S. J. DIJKSTRA pointed out that the stratigraphical value of the author's Table II would be greater if he could determine the megaspores shown in it.

In reply, W. S. LACEY, agreed with T. N. George that the uncertainty as to the age of the Lower Brown Limestone and Basement Beds in North Wales was a serious difficulty in the correlations proposed. To jump from the Avon Gorge to the Vale of Clwyd and from the Vale of Clwyd to Eskdale and Liddesdale on the evidence of not very numerous floral and faunal remains was perhaps to expect rather a lot ! The correlations suggested, however, were only tentative, and work was still in progress. He was very hopeful that when further plant material had been specifically determined, and especially when detailed work on the spore content of these beds had been carried out on the lines adopted by Mrs. E. M. Knox on the Limestone Coals of Scotland, much more precise correlations would be possible. In reply to S. J. Dijkstra, he said he had not yet made more than a preliminary study of the spore content of the Lower Brown Limestone. So far numerous Lycopodiaceous megaspores and several distinct kinds of microspores had been found. The megaspores were quite large, varying from 1 mm. to 2 mm. in diameter, and had a spiny outer surface and very well-defined tri-radiate scar. They appeared to be all of one kind and were referable to the form-genus *Triletes*, but to which type he was not as yet able to state.

THE PACIFIC—A MAIN CENTRE OF DISPERSAL OF EARLY PALAEOZOIC LIFE

By Y. C. SUN

China

ABSTRACT

Students of Palaeozoic stratigraphy have found that Chinese faunas are usually different from those of Europe and that stratigraphical correlation between Europe and Asia is extremely difficult. This has induced some authors to propose an unnatural correlation between certain Palaeozoic horizons in China and those of Europe and America.

After an investigation of European sections in 1926–28 and 1935–36, and a comparative study of the Palaeozoic in Yunnan and neighbouring provinces of south-western China during the recent war, the author is convinced that the Pacific was a main centre of dispersal of Palaeozoic life and prefers to use European standard systems. He will endeavour (1) to show that the Yunnan succession is complete and therefore the best fitted for recognition as the world's standard in classifying the Palaeozoic, (2) to point out that the graptolite faunas and other mero-Planktonic faunas should be given more weight in the approximate correlation between Europe and Asia, (3) to list some early occurrences of genera and species in the early Palaeozoic of China, (4) to give the geographical distribution of some Pacific endemic forms and also the possible route of migration of the faunas, and finally (5) to present more evidences of a close connection between the Mediterranean Sea and the Cathaysian Province through the common occurrence of some genera and species.

DISCUSSION

G. G. DELÉPINE fait observer que les recherches faits depuis trente ans dans le domaine de la Mésogée de l'ouest ont montré qu'au Dévonien et au Carbonifère nombre de genres, et même d'espèces, sont identiques à ceux qui ont été découverts dans le S.E. de la Chine, en Indo-Chine ou en Australie. Comme exemple, il cite *Daraelites praecursor* à la limite supérieure du Viséen, les genres *Sporadoceras* au Dévonien supérieur, *Aganides* et *Munsteroceras* au Tournaisien. Il cite aussi l'exemple de *Fusulinella bocki*, trouvé dans le calcaire moscovien inférieur des Asturies et dans le S.E. de l'Asie.

ECOLOGY AND CORRELATION OF THE PENTLANDIAN—A NEW DIVISION OF THE SILURIAN SYSTEM IN SCOTLAND

By A. LAMONT

Great Britain

ABSTRACT

The discovery of *Monoclimacis crenulata* (Törnquist) and *Spirograptus* aff. *falx* (Suess) in the Eurypterid and Starfish flags of the Pentland Hills suggests that, in the Pentlandian, coastal faunas extend upwards from the base of the *Monoclimacis crenulata* Zone of the Gala-Tarannon. The earliest beds seem locally to have accumulated slowly with algal limestone containing also *Metaharpes amiboueana* with circular cephalon and very large pits on the fringe, *Eophacops scotica* with spinose cheek surfaces, and, in shales, abundant *Acidaspis lothiana*, protected in clear water by its spines. In later Pentlandian beds the *Plectodonta* aff. *canastonensis* mudstones show possible increase in rate of sedimentation from the Deerhope, where it was slow so that abundant biconvex brachiopods and a few attached lamellibranchs flourished, to the North Esk, where freely moving lamellibranchs with strong anterior development are commonest. *Parmorthis* occasionally persists in the latter beds along with *Pisocrinus* aff. *campana*, but *Mendacella* is restricted to the Deerhope. Species of *Lichas* appear to show features of protective mimicry. The fish beds, which follow a coarse conglomerate, may be Wenlock, or they may mark the close of Gala sedimentation in the Pentlands. *Ateleaspis* from the Pentlands and Lesmahagow is definitely more primitive than *Aceraspis* and *Micraspis* from Rudstangen, Norway, where the stratigraphy requires revision. Beds 8a to 8d in Norway are almost certainly Gala-Tarannon. Other correlatives are the ea₂ beds of Czechoslovakia. In Podolia, the Ustievsky horizon and the Mushinsky stage may be Gala rather than Upper Llandovery. In the Central Himalayas, the Muth quartzite appears to approach to Pentlandian; and the Namshin sandstones in Burma reach about the same level. In general conditions appear to have been more severe in the Gala-Tarannon and Ludlow than in the Wenlock.

COASTAL faunas of the Gala-Tarannon are poorly known from the Wrexham district. At Tarannon itself E. M. R. Wood recorded only graptolites. But in the Gutterford Burn, in the Pentland Hills, it has now been verified from the occurrence of *Monoclimacis crenulata* and *Spirograptus* aff. *falx* (Suess), that the associated eurypterid, trilobite, starfish, and brachiopod assemblage belongs to the Upper Gala, and not to the Wenlock as was thought by earlier workers. The succeeding, richly fossiliferous, *Plectodonta* aff. *canastonensis* mudstones of the Deerhope and North Esk also appear to be pre-Wenlock, and this may even apply to the beds at the Henshaw Burn which yield abundant *Niculites* cf. *cawdori* and *Grammysia* cf. *mcadamensis*, along with an *Encrinurus*, not unlike *E. calgach* of the *Plectodonta* mudstones, and *Mimulus* (?) cf. *incertus*, a known Lower Gala form from Penkill at Girvan. The fragments of primitive fishes—*Birkenia*, *Lasanius*, and *Ateleaspis*—from Red Beds at the top of the Pentlands succession, though separated from the older beds by a striking Red Soda-Granite conglomerate, may not be very much younger than the rest of the Silurian sequence. A Wenlock date has been tentatively assigned to them (Lamont, 1947). This is in keeping with Stetson's contention that if the elasmobranchs and ostracoderms are related then the common ancestry must date back "long before the Ludlow."

Emergence of land and possible tidal flats characterize the lower part of the Pentlandian in the Green Cleuch area, where deposition was in shallow water. Washed out worm-tubes of *Monocraterion* cf. *clintonense* and occasional shells of *Lingula monina* are taken as indicating that the silts were laid down slowly. *Lingula* aff. *lewisi* and *L.* aff. *symondsi* are also fairly common in the Gutterford section, but are much less common in the more quickly accumulating parts of the *Plectodonta* mudstones. The Green Cleuch area also yields *Buthotrephis* and *Stylomurus*. Nearby, at Bavelaw, *Acidaspis lothiana* is the predominant trilobite. Probably it was very visible in shallow water, but its spines deterred

predacious creatures from swallowing it. Another trilobite from these early translucent waters is known from a single eye and cheek from a boulder of fragmental limestone out of the Lower Old Red conglomerate at Loganlee. This is *Eophacops scotica*, which has many facets per radius in the eye and a group of spines on the surface of the cheek. No other *Eophacops* seems to have quite such an armature. But in the most slowly deposited of the Plectodonta mudstones, at the Deerhope, six or seven short spines rise vertically from the upper surface of the free cheek of *Acidaspis dealgach*, probably also indicating a form living in clear water. In the fragmental Gala limestone a large *Harpes* with almost circular cephalon has been found. The circular outline may have given powers of quicker "turn-round" than in the case of the sub-oblong *Harpes domina* (Lamont) from the North Esk muds. The latter has a minutely punctate fringe which probably helped to disguise the animal against its customary background of silt and mud, as well as serving a sensory function. *H. domina* shows wound-scars or lesions on the fringe. It may have been in special danger at the period of ecdysis. There is a characteristic, branching system of sutures over the alae, possibly to secure the ready freeing of these organs during emergence of the soft parts. This has been made a ground for founding the genus, *Scotoharpes*.

Lichidae have never been found entire in the Pentlands. Muscular connection between different parts of the exoskeleton may not have been strong. Both in the small, convex species *Lichas* (*Euarges*) *hendersoni*, from the Deerhope, and in the pygidium of a new subgenus from the North Esk, there are features suggesting protective mimicry. In lateral view the anterior bicomposite lobes of the glabella of *L. hendersoni* look like large eyes of a creature much bigger than the actual possessor, and doubtless so appeared to possible predators including *Kionoceras*, *Polygrammoceras*, *Spyroceras* and similar cephalopods which, on the analogy of modern forms, may have had well developed eyes and considerable powers of mental association. The new subgenus was a flattened form of Lichid, in which the pygidium had three pairs of projecting, longitudinally striated spines. Inside these, on the margins of the rachis, there were a pair of "eye-marks." This display may have been enough to divert an enemy approaching from behind.

Other trilobites fairly common in the shallower, more richly brachiopod-bearing part of the Plectodonta mudstones, are species of *Calymene* and *Cyphoproetus*. They are found at the Deerhope, and penetrate into Wetherlaw Linn. They are always dismembered, although in the Lower Gala muds of Hadyard Hill, near Girvan, a related *Calymene*, but without upturning of the anterior brim, can be found entire, usually with its pygidium sharply turned downwards. At the Deerhope little, prickly specimens of *Youngia*, and *Proetus peeblesi* with a long, narrow, conical glabella are occasional in their appearance. *Cromus*, with glabellar lobes each bearing several tubercles, is present as fragments assigned to two species. On the other hand, *Encrinurus* and *Eophacops* are frequent and often complete. They were stream-lined and strong swimmers and persist in all phases of deposition of the Plectodonta mudstones. Two species of *Encrinurus* may be distinguished. One with elongate, narrow glabella, no basal lobes, and a single posterior row of tubercles on the fixed cheek, has been called *E. pluc*. Its companion has a wide glabella and two rows of tubercles laterally, and a variety of it persists into the later silts at Henshaw Burn. Some specimens of *Eophacops* at the Deerhope are quite corpulent.

In assessing rates of sedimentation importance has been attached to the lamellibranch faunas. *Nuculites* cf. *cawdori*, *Grammysia* cf. *mcadamensis*, *Prolucina lucina*, and other active nestlers and hoppers, have, in the absence of attached forms and vertical burrowers, been considered to indicate steady sedimentation. This applies to the Henshaw silts and the North Esk part of the Plectodonta mudstones. It was at the Deerhope where sedimentation was slower that John Henderson and earlier collectors obtained such attached forms as *Ambonychia hendersoni* and forms of *Pterinea* which lay on one valve. *Orthonota salteri*, with low umbones and parallel dorsal and ventral margins, also mainly from the Deerhope, was adapted to quick burrowing, possibly where there was greater danger from seasonal erosion than from complete burial by rapid sedimentation. The robust width and acuminate posterior of shells like *Orthonota amygdalina* var. and *Grammysia* cf. *undata* suggest general stability

and power to escape following sudden burial. The close approximation of inhalent and excretal openings would be no disadvantage in other than very still water. *Goniophora* cf. *antiqua*, with oblique fold from umbo to posterior lower margin, and *Grammysia* aff. *cingulata*, with oblique sulcus, both occur in the Pentlands, though their exact station is not known. Fold and sulcus may have fulfilled a double function in allowing water to drain towards the inhalent opening when the shells were submerged in silt and in acting as elevators for a too deeply buried animal still capable of moving forward by means of its foot. *Modiolopsis* attached by a byssus has not been found in the Pentlandian, but *M. mimus* is very abundant at Muirkirk and Lesmahagow, where it assumes a diversity of shapes. From a collection lent me by Mr. Ronald Tripp, it may be suggested that the larger forms are those with great development of the posterior part of the shell, i.e., extension of the margin where food and oxygenated water were drawn in. Special advantage would accrue to forms which carried the inhalent margin high above the sea-floor and surrounding competitors.

Earlier conclusions of the author on the relations of brachiopod morphology to environment are mostly substantiated in the Pentlandian. But some further points may be made. The most interesting is that in *Plectodonta* at the Deerhope the typical denticulations of the hinge on either side of the umbo are well developed, but in the deeper, quieter waters of the North Esk locality these have disappeared, so that one might there attribute *Plectodonta* aff. *canastonensis* to the genus *Sowerbyella*. In one layer *Bilobites parallelus* is common with ostracods. Distance between inhalent and exhalent openings may have provided it with a special advantage where locally there was reduced movement of water. The quiet conditions of deposition of the *Plectodonta* mudstones at the North Esk are indicated by the occurrence of entire, small examples of *Pisocrinus* cf. *campana*. Another key to varying conditions in the *Plectodonta* mudstones is that at the Deerhope one finds the only occurrence of *Leptaena* with sharply interrupted rugae, similar to those in *L. wisgoriensis* from shallow, well illuminated, Upper Llandovery beds. The *Atrypa* aff. *reticularis* of the *Plectodonta* muds is biconvex with large body-space and, like the even more rotund *Rhipidomella pentlandica*, it does not normally reach the North Esk outcrop, though abundant at the Deerhope and in Wetherlaw Linn. The biconvex *Mendacella deerhopensis* is likewise restricted, but less so a small plano-convex *Parmorthis*. A variety of the last mentioned is also found in the Limestone band in the Gutterford Burn, where it has a deeper, more oblong delthyrial cavity, but elsewhere in the Gutterford section the Dalmanellacea are represented by rare *Levenea* aff. *canaliculata*, in which the interior of the adult brachial valve shows peculiar crescentic, outwardly convex ridges in front of the crura, suggesting relationship with *Idiorthis*. The shell is narrowly lenticular, hence adapted to muddy environment, but it also seems to occur in Gala limestone blocks from the local Lower Old Red Sandstone.

Before leaving the discussion of ecology of the Pentlandian faunas, one may point out that in the Gutterford Burn many Dendroidea as well as other graptolites are found in the same dirty sandstones and flags as are the well known Eurypterids. Species present belong to *Coremagraptus* and *Dictyonema*, and associates include occasional *Aulopora* sp. and *Lingula* aff. *lewisi*.

The appearance of *Dictyocaris ramsayi*, *D. salteri*, and *D. slimoni* in the Gutterford beds along with *Monoclimacis crenulata* and *Spirograptus* aff. *falx* casts great doubt on the use of *Dictyocaris* for zonal purposes in areas like that of the Stonehaven Silurian and at Lesmahagow, where *D. slimoni* is the typical form. *D. slimoni* also reaches as high as the Trimpey beds in the West Midlands of England, where it appears to be Downtonian, and there is a variety, *D. slimoni* var. *tuberculata*, in the Rudstangen, Ringerike, district of Norway, where it occurs along with *Aceraspis* and *Micraspis*, fishes further evolved than those of the Pentlands and Lesmahagow, but certainly earlier than Downtonian. Kjaer and Campbell both associated the Rudstangen fauna with that of Cowie, near Stonehaven, and regarded each as Downtonian, but this largely arose from the mistaken identification of "Ludlow" and "Wenlock" species of invertebrates in the subjacent beds. At Ringerike a large part if not all of Beds 8a to 8d is almost sure to be Gala-Tarannon, while, though *Chonetes striatellus* has been recorded at two levels in Beds 9a to 9f, it may be doubtful whether this is the true, large *C. striatellus* of the English Ludlow. In the Pentlands records of "*C. striatella*" refer mostly to *C. cf. novascoticus*

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and to a new species with spines fewer, longer, and more at right angles to the hinge-line than in true *C. striatellus*.

Much importance attaches to Heintz's stratigraphical arrangement (1939) of the principal fish faunas of Northern Europe according to their evolutionary relations:—

- (6) West of England fauna with *Hemicyclaspis murchisoni* (Egerton)—Lower Downtonian.
- (5) Jeløy fauna of Norway with *H. kjaeri* (Heintz).
- (4) Rudstangen fauna of Norway with *Micraspis gracilis* Kjaer and *Aceraspis robusta* Kjaer.
- (3) Pentland Hills and Lesmahagow fauna of Scotland with *Ateleaspis tessellata* Traquair.
- (2) Skane fauna of Sweden.
- (1) K₁ fauna of Oesel, Estonia.

Lungershausen & Nikiforova (1942) do not exclude a Wenlock age for the K₁ fishes of Oesel, and correlate the dolomite with *Eurypterus fischeri*, under the fish beds, with the Wenlock Shale. As they do not appreciate the stratigraphical value of the Gala-Tarannon, they have crowded the whole of the Lower Oesel Group (I) and the top of Group H with *Pentamerus esthonus* and *Bumastus barriensis* into the Upper Llandovery. The Lower and Upper Oesel Groups (I and K) are regarded by Northrop (1939) as Middle Silurian, and compared by him with the West Point and Indian formations in Gaspé. All this points to the likelihood that the K₁ fishes of Oesel are not later than Wenlock. Further work is required to solve conclusively the problem of the relative dating of the earlier items in Heintz's list, but for the present the writer draws attention to the fact that *Aceraspis* and *Micraspis* at Rudstangen have the pectoral fins much more elongated than in the very primitive Scottish *Ateleaspis* which stands right at the beginning of Cephalaspid lineages.

It seems arguable that the volcanic conglomerate containing rhyolite and hornblende-andesite below the beds with *Traquairaspis campbelli* and *Dictyocaris slimoni*, at Cowie, near Stonehaven, may be Gala or Wenlock. Whether at the top of this sequence the red and green tuffs and brown tuffaceous sandstones represent a vulcanism of different—say Ludlow—date is doubtful. The thickness of the Silurian from the mouth of the Cowie Water to Ruthery Head reaches 1,960 feet, but it might be a mistake to try to divide it among different English formations. The earliest volcanic ashes are in the Purple Sandstones, over 1,100 feet below the *Dictyocaris slimoni* beds, and this suggests to the writer that possibly we are dealing with much the same vulcanism as that manifested in the late Valentian at Tortworth, and that this vulcanism ensued upon earth-movements involving pressures between west-north-west and east-south-east, of which the effects have been described by O. T. Jones in the Llandovery district of South Wales. A search is being made for possible Gala ashes further south in Scotland, and it is hoped that an area at Abington may yield Gala-Tarannon graptolites. What relationship there may be with the Chaleur Bay vulcanicity, apparently in the Ludlow, described by Northrop, remains to be seen. If we think of the Gala and Ludlow as periods of uplift, with acid volcanoes exploding in fine ash which might reach the upper atmosphere and avert some of the heat rays of the sun, we may explain the more severe conditions of these epochs as compared with the intervening Wenlock with its large crinoids and large graptolites. If we judge from mere size of graptolites, the main orogenies of the Ordovician and Silurian in North-West Europe fell in the Llanvirn (Bifidus time), in the Ardwell Flags epoch of the Caradocian, possibly in late Ashgillian (pre-Hirnantian), in parts of the Llandovery and Gala, and towards the end of the Wenlock when small *Cyrtograptus lundgreni* replaces the large, many-stiped *Cyrtograpti* of the earlier Wenlock. This fits in well with Vogt's views (1936, 1945) on the orogenies of Northern Norway *vis-à-vis* those of Scotland.

In Czechoslovakia the Pentlandian is equivalent to the lower part of the ea₂ beds, and the importance of the Gala-Tarannon in the Eastern Alps is seen from the work of Dr. Hemmann. In Podolia the Ustievsky horizon and the Mushinsky stage may be Gala rather than Upper Llandovery.

The Silurian succession at Spiti, in the Central Himalayas, ends with the Muth quartzite at a level perhaps near that of the Pentlandian. Fossils from Cowper Reed's Horizons 7 and 8 ancestral to or related to Pentlandian species include:—

Levenea (?) *muthensis* (Reed), like, but simpler than, *L.* (? aff. *Idiorthis*) *gutterfordensis*;

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"*Leptaena rhomboidalis*," very like a Deerhope form;

Palaeoneilo cf. *victoriae* Chapman, quite near a rare Deerhope lamellibranch;

Encrinurus aff. *punctatus* Brünnich, like a variety of *E. calgach* from Deerhope, Henshaw Burn, etc. In the North Shan States of Burma, the Namshin Sandstones appear to correlate with the Pentlandian. They have in the past been classified with the Wenlock, but only a form like *Dalmanites longicaudatus* var. *orientalis* at Panhsa-pyé has a really Wenlock Shales appearance. Namshin species comparable with Gala-Tarannon species include:—

Orthoceras cf. *tenuiannulatum* McCoy;

"*Schuchertella*" *planissima*, resembling an undescribed species from the Limestone band in Gutterford Burn;

Levenea aff. *canaliculata*, like specimens from *remanié* Gala in Lower Old Red Sandstone at Loganlee;

Nucleospira pisum;

Encrinurus konghsaensis, like *E. calgach*, but distinguished by well developed basal glabellar lobes, so that *E. konghsaensis* may be the more primitive of the two.

Pentlandian *Encrinurus calgach* seems to be related to *E. mitchelli* from the Lower Trilobite Bed (Yass and Hume Series) of Bowning, New South Wales. In the same deposit *E. bowningensis* compares with another Pentland species, *E. pluc*, previously compared with *E. onniensis* from the Upper Llandovery of Shropshire. *Harpes trinucleoides* from Australia is also related to *H. domina* from the Pentlands, but its authors, Etheridge Jnr. & Mitchell, do not refer to a branching suture on the ala. The latter biocharacter in the Scottish species has been taken as of generic value, and may indicate that in *Scotoharpes* the alae, at least in ecdysis, had some important, possibly sensory, function.

Even high Pentlandian beds, like those at the Henshaw Burn, do not seem later in North American terms than a formation like the McAdam in the Middle Silurian of Arisaig, Nova Scotia. Correlation here depends on forms like *Calymene* cf. *antigonishensis*, *Kionoceras angulatum*, *Nuculites* cf. *cawdori* and *Grammysia* cf. *mcadamensis*, but appears trustworthy enough. One may assume that forms comparable with those in the Benson Knott, etc., beds of the Lake District need not be as late as "Upper Ludlow," but much further work is required. In the Black Cape district of Gaspé, the Pentlandian may compare with formations like the Anse Cascon and La Vielle, if with nothing higher. In New York State the Pentlandian seems to fall within the diachronous Shawangunk Grit.

One thing which becomes quite clear from this discussion is that non-marine conditions supervened at various times in different areas of the Silurian, and that orogenic conditions, erosion phenomena, and red beds are as likely in the Gala as in the Ludlow.

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ZONAL CORRELATIONS BY MEANS OF CONODONTS

By E. B. BRANSON and M. G. MEHL

U.S.A.

ABSTRACT

In the United States, conodonts have been found from Lower Ordovician to Upper Permian formations. The Lower Ordovician conodonts are the oldest fish remains that have been described. Various groups of formations of each period can be distinguished by conodonts and certain genera are distinctive of each group. For example, the genus *Icriodus* has been found in every Devonian formation in North America that has yielded conodonts and has not been found in other periods. It is also known from central Germany, the only place from which Devonian conodonts have been reported in Europe. Lower Ordovician conodont genera from Esthonia, which were first described by Pander, are present in Lower Ordovician formations in North America, but not more than five of them have been found in any of the localities in Europe excepting Pander's original localities. The number of genera decreased greatly from the Mississippian to the Pennsylvanian and from about twenty genera in the Pennsylvanian to about five in the Permian.

DISCUSSION

CHR. POULSEN asked if all of the many different types of conodonts had been studied with regard to their systematic position, or if there was still the possibility that at least some of them were jaws of annelids or parts of the radulae of gastropods.

B. F. HOWELL said that although the authors had stated that their Lower Ordovician conodonts were probably the oldest traces of fishes yet discovered, nevertheless two impressions of what appear to have been fish plates similar to the plates found in the Ordovician Harding Sandstone of Colorado had, however, been found in the Middle Cambrian St. Albans Shale of Vermont. These had been described by W. L. Bryant as the impressions of the plates of a chordate, which he named *Eoichthys howelli*. The speaker hoped that anyone who was interested in these Vermont fossils and who had an opportunity to visit him at Princeton, New Jersey, where they were kept in the palaeontological collection of Princeton University, would examine them and express an opinion as to their relationships.

C. J. STUBBLEFIELD recalled that some sixteen years ago E. B. Branson had interested him in conodonts and that in the intervening years the publications of Branson and his colleagues had enabled the speaker to identify generically conodonts newly discovered in Upper Carboniferous strata in eight of the British coalfields. He enquired whether the authors had found conodonts in any positively non-marine strata, and also whether, as the title of the paper implied, conodonts had been used in zonal rather than stage correlations. He expressed the hope that the authors or some of their American colleagues would publish soon in a single volume a series of illustrations of the conodonts characterising the Ordovician and succeeding formations.

E. B. BRANSON, in reply, said that the composition of conodonts (calcium phosphate) seemed to preclude their being from annelids, which have hard parts composed of chitin. Many conodonts are attached to fragments of primitive bone. Gastropods have radulae composed of silica and conodonts cannot be such radulae. Some faunas contain many conodonts but no gastropod shells. Some faunas made up of many gastropod shells contain no conodonts. These three facts seemed to preclude the possibility of the conodonts being derived from gastropods. In answer to C. J. Stubblefield, Branson observed that the paper was a discussion actually of the correlation of formations and not of zones. However, he and his colleague had been able to correlate zones over rather large areas. They had found no conodonts in non-marine sediments.

TOURNAISIAN FACIES IN BRITAIN

By T. NEVILLE GEORGE

Great Britain

ABSTRACT

The archipelagic environment of British Tournaisian sedimentation is reflected in rapid lateral changes in lithological and faunal facies.

The Clevedonian division of the type Avonian has a readily identifiable base where the underlying rocks belong to the Old Red Sandstone (though its artificiality is demonstrated by the occurrence of marine intercalations with *Spirifer verneuili* in the uppermost red sandstones). But in Devon and Pembrokeshire the well-represented Strunian is only arbitrarily distinguished from the marine Famennian beneath; and the Devonian-Carboniferous junction is of Ardennes facies.

In northern Britain the restricted fauna of the Lower Tournaisian makes correlation with the type Avonian very difficult; and it is not improbable that rocks of Old Red Sandstone facies are of Carboniferous age in Scotland.

The Zaphrentis and Lower Caninia zones of the type-Avonian cuvette show marginal facies on the flanks of contemporary up-warps. These may be crudely different, as between sandstones and limestones; but mostly there are subtler variations within the calcareous facies. A strong development of oolites and algal, calcitic and dolomitic mudstones, mostly without brachiopods and corals, indicates lagoonal conditions flanking St. George's Land. In northern England and Scotland the cementstone facies is dominant, while such intercalated "normal" beds as occur contain species mostly not found in the south, and correlation with the type Avonian is precarious.

I. THE TOURNAISIAN BASE

THE varying criteria adopted to define the Tournaisian base reflect the differences in the nature of the Devonian-Carboniferous junction in different parts of Europe. The early practice in Belgium and France of placing the Assise d'Etroeungt in the Famennian was a comment on the lithological continuity of the Strunian terrigenous beds with those of the underlying Assise des Psammities du Condroz. The no less natural distinction between the Old Red Sandstone and the Carboniferous Limestone, marked by abrupt and extreme lithological contrast, which Vaughan utilized to define the base of the Avonian series in the South-Western Province, inevitably linked the whole of the Lower Limestone Shales with the beds above and separated them from the beds beneath. In both cases facies was confirmed (or taken for granted) as a sound basis for stratigraphical classification.

In one aspect stratigraphical nomenclature is essentially no more than a matter of terminological definition; and the subsequent adjustment of the Famennian-Tournaisian junction in Belgium by its transference from the top to the bottom of the Strunian beds was (once the correlation was accepted) simply an acknowledgment that on a regional scale the Cleistoporan base was a more convenient datum to adopt than any other—a datum locally recognizable at the top of the "lagoonal" Assise d'Evieux. But in another aspect this adjustment at the same time implied that the Cleistoporan base could not only be located by convention at an agreed horizon, but also be recognized on "objective" stratigraphical evidence at an identifiable horizon. It also implied that a diastrophic change in one area (the flooding of the Welsh cuvette of Old Red Sandstone by the transgressive Carboniferous sea) was a suitable foundation for more extended stratal subdivision.

Over most of Britain outside Devon the recognition of the Cleistoporan base, though professedly dependent on the occurrence of diagnostic Cleistoporan fossils, in practice rests in the lithological contrast between red sandstones and grey calcareous shales. The fossils in the shales are in fact no more than an incidental expression of changing conditions of sedimentation: they are not, except on other grounds than their mere occurrence, intrinsically definitive of Carboniferous as against Devonian

rocks, and they are less of Cleistoporan age (though it happens they are that) than members of a Cleistopora-zone facies assemblage. Such a stratigraphical datum, palaeontologically equivocal in character, is notoriously defective in being both local and diachronic. Schindewolf (1926, 1928, 1936), summarizing much German work, has contended it should be replaced by a criterion at once "rational" and "trustworthy," which he has found in the cephalopod sequence as established in regions where there is a continuously marine Devonian-Carboniferous sedimentary series. Incidentally, following the argument of his thesis, he has upheld former practice in placing the *Wocklumeria*-Stufe, approximately equivalent to the Cleistopora zone, and the *Gattendorfia*-Stufe, ranging probably as high as the upper Zaphrentidan, in the Devonian*, a view partly endorsed by Hudson & Turner (1933).

On grounds of abstract theory Schindewolf's contention has no doubt much to be said in its favour. But in Britain it breaks down in practice because of the great rarity—almost complete absence—of goniatites in the lowest Avonian beds. The *Wocklumeria*-*Gattendorfia* sequence, established mainly in western Germany, is completely unknown in the "Famennian" marine Pilton Beds and Entomis Shales of Devon—and indeed is scarcely better represented in the Ardennes. The only cephalopod links between Britain and the Continent are provided by a doubtful clymeniid and occasional specimens of *Imitoceras* found near Barnstaple and Fremington (Paul, 1937, p. 435); and by a solitary specimen of a prolecanitid found in the Lower Limestone Shales near Abergavenny†.

Paul (1937, p. 440) has endeavoured to identify an areal succession of sub-parallel facies-belts in the Pilton Beds and their assumed equivalents in north-west Europe; but his divisions, while they indicate a probable southward off-shore deepening, do not hold in any detail in Britain: only by emphasizing selected elements in the several faunas is it possible to accept them: and in any event they are not applicable to the ground north of the Bristol Channel. Similarly, Vaughan's assumption of a widespread development of a lagoonal *Modiola* phase (K_m) at the base of the Cleistopora zone, forming a group of strata transitional from the Old Red Sandstone, obscured a marked variation in the lowest Avonian sediments when they are traced over comparatively short distances in the South-Western Province. An analysis of local faunal assemblages, in terms not merely of lists of species but also of numerical proportions of individuals, reveals a variety of sub-facies to characterize the Cleistopora zone and its equivalents in Devon and Belgium. They cause difficulty in establishing precise and acceptable correlation, and in making detailed palaeogeographical inferences.

II. THE CLEISTOPORA ZONE IN THE SOUTH-WESTERN PROVINCE

The Skrinkle Sandstones contain a fauna (with *Spirifer verneuili*, "*Rhynchonella*" *laticosta*, *Ptychopteria damnoniensis*) which, though restricted, is a fairly satisfactory basis for regarding them as Famennian in age and for correlating them with the Marwood and lowest Pilton Beds of Devon (Dixon, 1921, p. 50). But the succeeding lowest beds of the Lower Limestone Shales, to which they are apparently completely transitional (and in which *Myophoria deltoidea* is found), are characterized by a faunal assemblage very different from that of the upper Pilton Beds, equally transitional from the underlying strata. Indeed, in Devon very few of the typical Cleistoporan fossils occur, even rarely: *Spirifer tornacensis*, syringothyrids, *Spiriferinella* spp., *Cleiothyridina* cf. *roissyi*, *Camarotoechia mitcheldeanensis*, *Hustedia carbonaria*, and *Chonetes* cf. *hardrensis* appear to be completely or almost completely absent. Conversely, *Spirifer verneuili* and dalmanellids, common in the upper Pilton Beds and having Devonian affinities (being also found in the Belgian Strunian), are almost unknown in the Lower Limestone Shales in the South-Western Province‡.

On the other hand, productids typical of the Strunian stage (*Avonia praelonga*, *Buxtonia* cf.

* More recently, Schindewolf (1939; see also Paeckelmann & Schindewolf, 1937) has placed the *Gattendorfia* beds ("Oberdevon VII") in the Tournaisian ("Unterkarbon I").

† I have to thank Dr. C. J. Stubblefield for drawing my attention to the existence of this specimen.

‡ A *Dalmanella*-like orthid is not uncommon near Stoke Lane in the Mendips.

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scabricula, productellids) are likewise absent from or rare in both the Skrinkle beds and the Lower Limestone Shales of Pembrokeshire; but they are found in the Pilton Beds, and are common in the lowest Cleistoporan beds of Gower (George, 1939), where they are associated with *Spirifer tornacensis*, *Spiriferellina* spp., *Chonetes* cf. *hardrensis*, and schellwienellids.

Correlation is clearly dependent on the relative emphasis placed upon the respective faunal elements, and any conclusion reached may be in part a cyclical result following arbitrary classification. Thus the separation of the Skrinkle Sandstones from the Lower Limestone Shales is primarily a lithological one, being based on the highest occurrence of red beds (Dixon, 1921, p. 67). Where red intercalations are reduced to insignificance in the Skrinkle Sandstones, as at Freshwater West (Dixon, 1921, p. 52), the grey shales of the group, not readily to be distinguished on lithological characters from the "true" Lower Limestone Shales, contain *Spirifer verneuili* and other "Upper Devonian" fossils. The occurrence of a Skrinkle fauna in the highest red quartzitic grits and sandstones of the Old Red Sandstone of the Breconshire North Crop does not then necessarily confirm the age of these "Breconian" sediments as uppermost Devonian, or the reference of the overlying Grey Grits to the Avonian series.

It has long been recognized that K_m in the South-Western Province is not to be looked upon as a sub-zone characterized by a faunal assemblage of precise age, but as a rock-type having merely phasal significance. Not only are modiolids and other lamellibranchs common at various horizons throughout the Cleistopora zone, but the individual species are more or less long-ranging forms (so far as they are known at present: it is probable that refinements of identification would make them much more useful zonal indices than they have hitherto proved to be). Thus *Modiola lata* itself is recorded from various zones of the Avonian, as also are a number of its associates like the nuculids and the sanguinolitids: for instance, *Sanguinolites* of *abdensis* type, not uncommon in the lowest Cleistoporan beds of South Wales, is the characteristic member of the "Abden fauna" of the Lower Limestone Group of Scotland, where it falls into the Dibunophyllum zone, and where it is found with taxodonts like *Nucula gibbosa* and *Nuculana attenuata*. Similarly, *Myophoria deltoidea*, a common Upper Devonian form of Devon, is abundant in the Lower Limestone Shales some 50 feet above the top of the Skrinkle Sandstones in West Angle (Dixon, 1921, p. 116), and occurs at approximately the same horizon in Gower.

No doubt K_m , where it occurs as a basal phase, reflects conditions of sedimentation transitional between Old Red Sandstone and Carboniferous Limestone; but at a great number of localities in the South-Western Province the initial incursion of the Carboniferous sea was sufficiently rapid to establish almost immediately normal marine conditions, the lowest Cleistoporan beds containing a fairly rich fauna particularly of brachiopods (though Strunian corals are everywhere absent). Both in number of individuals and variety of kinds the assemblages of the lowest beds of the Lower Limestone Shales may be as rich as those of upper K_1 and K_2 . This basal fauna not infrequently is (as yet) scarcely distinguishable in any respect from faunas at various horizons up to the base of the Zaphrentis zone: locally containing abundant specimens of *Spirifer tornacensis*, syringothyrids, *Spiriferellina* spp., and *Dictyoclostus vaughani*, together with the almost ubiquitous athyrids and *Camarotoechia mitcheldeanensis*, it renders meaningless Vaughan's original subdivisions of the Cleistopora zone. Such a rich fauna in beds within a few feet of the Old Red Sandstone occurs, for instance, in the Forest of Dean (Sibley & Reynolds, 1937, p. 34), along much of the North Crop in South Wales (Robertson, 1933, p. 36; George, 1927, pp. 53, 69), and in Pembrokeshire (Dixon, 1921, p. 117). Often there is then no observable transition from one formation to the other: the knife-edge contact between the Lower Limestone Shales and the Grey Grits in parts of Breconshire suggests non-sequence if not unconformity. At the same time, temporary reversions to "lagoonal"* facies are marked by beds crowded with modiolids (and other lamellibranchs) at various horizons in both K_1 and K_2 .

* The term "lagoonal" is misleading. The mere occurrence of molluscan layers is not to be taken as indicative of peculiar conditions of sedimentation.

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In the result, the Cleistopora zone (of which the limits are significantly coincident with those of the lithologically defined Lower Limestone Shales) appears as a series of shales and limestones of generally uniform facies that are recognized to belong to the zone less because they yield a characteristic fossil assemblage—perhaps *Avonia bassa* is the only satisfactory zonal form—than by their stratigraphical position between unfossiliferous red sandstones below and coral-bearing limestones above. There can be little doubt that the zone is homotaxially equivalent in whole or in part to the Assise d'Etroeungt, and the lower beds of the zone in Pembrokeshire and Gower are probably to be correlated with the upper Pilton Beds of Devon. But the zone is in essence only a lithological entity, a transitional interpolation between contrasted facies of whatever age (compare Schindewolf, 1928).

III. THE CLEISTOPORA ZONE IN THE CENTRAL PROVINCE

It is possible that some of the red basement beds of the Avonian series in North Wales are referable to the Cleistopora zone, since they contain in places common camarotoechiids and finely striate chonetids. (If this should prove to be the case, there occurs between them and the overlying Dibunophyllum zone a major stratigraphical break that may be correlated with the Nassauian intra-Avonian unconformity in South Wales.) With this possible exception, the zone is not known to come to outcrop in the Central Province.

Hudson (1938) however has given an important summarized account of sediments penetrated in a borehole near Skipton, where some 200 feet or more of mudstones, shales, and limestones contain "faunas comparable to those of the Lower Limestone Shales of K age in the south of the British Isles and also to those of the Assise d'Etroeungt of Strunian age in Belgium and France." This new evidence, as Hudson indicated, throws welcome light on early Tournaisian geography in revealing continuity of sedimentary facies between the South-Western Province and the Central Province, presumably around the western flanks of St. George's Land.

At the same time the correlation clearly illustrates the dependence on facies that is inherent in the recognition of the zone. Hudson suggested a Cleistoporan age for the beds partly on the evidence of their associates. On the one hand, they are underlain by strata which have the facial aspect, and may be the equivalents, of the Skrinkle Sandstones—strata which are non-calcareous (though as they were originally shelly they may be decalcified) and contain an abundant fauna of modioliform lamellibranchs: but beds rich in modiolids are recurrent not only in Upper Devonian but also throughout the Cleistopora and Zaphrentis zones in the southern British outcrops (even in massive oolites in parts of South Wales), and the molluscs are not to be looked upon as indicative of any precise age until much more is known of their detailed morphology and distribution. On the other hand, they are overlain by mudstones with zaphrentids, allocated because of the corals to the Zaphrentis zone: but the presence or absence of *Zaphrentis* is a negative criterion, useful as it happens for recognizing the Cleistopora-Zaphrentis zonal junction in the South-Western Province but inapplicable to Belgium where the Strunian fauna includes species of several genera of rugose corals, including zaphrentids; and there is no reason to suppose *a priori* that strata truly of Cleistoporan age in the Skipton succession are necessarily without zaphrentids.

IV. THE TOURNAISIAN STAGE NORTH OF THE CRAVEN FAULTS

The Cleistopora zone is recognizable in the South-Western Province on certain lithological and faunal attributes. In terms of those attributes it is meaningless to talk of the Cleistopora zone in the Northern and Scottish Provinces, though there can be little doubt that beds of Cleistoporan age form part of the Tuedian succession.

The Cementstones facies, thickly developed in parts of Cumberland and Northumberland, is apparently conformable to, and in its lowest strata inosculates with, the Old Red Sandstone. Partly on this basis it has usually been regarded as belonging to the Tournaisian, possibly spanning the whole of that stage. In Cumberland and Liddesdale the reference of the Fell Sandstone to the Upper Caninia zone tends to confirm this correlation, though manifestly cementstones are variably developed in

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different parts of the north-English and south-Scottish outcrops, and as "lagoonal" deposits alternating with more normal fossiliferous marine layers constitute a local and recurrent facies.

In the Midland Valley of Scotland the general absence of marine beds below the Lower Limestone Group makes a recognition of the Tournaisian limits, even in the most general sense, extremely difficult. The Oil Shales, overlying comparatively thin Cementstones in the Lothians, appear on the evidence of the occasional goniatites they contain to be of B_2 (D_1 – D_2) age: this, if there is no discontinuity in the succession, would imply that some 600–700 feet of Cementstones are referable to the whole of the Tournaisian plus the lower part of the Visean stage; whereas in northern England the Cementstones may reach thicknesses of perhaps 4,000 feet, all presumably restricted to the Tournaisian stage.

The Randerstone limestones not far above the base of the Cementstone series in Fife contain a species of *Camarotoechia* which may be the same form as *Camarotoechia proava* of the *proava* beds of Liddesdale and Westmorland (Macgregor, 1931, p. 476; Garwood, 1931, p. 129). On this rather tenuous foundation, and on the further assumption that the *proava* beds fall into the Lower Caninia zone (though the definitive faunal assemblage of the zone in northern England is very different from that of the South-Western Province), it is to be inferred that the thin underlying Cementstones belong to the Zaphrentis and Cleistopora zones.

Nevertheless, the great thickness of beds of similar facies in northern England makes it doubtful whether the peculiar lithology of the Cementstones of Scotland—lagoonal of a special type: dolomite- and calcite-mudstones with at best a restricted fauna of lingulids and molluscs—necessarily indicates slow deposition. The palaeontological evidence being virtually nil, and the inference dubious, it is as yet no more than a speculation to suggest that the cementstones of the Midland Valley—especially those (the Ballagan beds) of the Glasgow district—may represent only the upper part of the Tournaisian. Their apparent conformity with the beds beneath would then be interpreted as a continuation of Old Red Sandstone conditions into Tournaisian times. That is, it is possible that some of the "Upper Old Red Sandstone" of the Glasgow district may be of Cleistoporan age: a view already put forward on other grounds by Kennedy.

V. THE TOURNAISIAN-VISEAN JUNCTION

Vaughan early came to recognize that zonal subdivision on a basis of faunal assemblages was not strictly dependent upon the evolutionary succession of species and genera which he initially supposed to be the case. When he considered *Lithostroton* to be descended from *Caninia*, its sudden incursion at the top of the Caninia zone seemed an obviously convenient means of distinguishing the Kidwellian from the Clevedonian stage, though it overlapped the complementary disappearance of *Caninia* (Vaughan, 1905, p. 264). It is still not possible, however, to demonstrate (what is indeed improbable) that the incoming of *Lithostroton*—a cryptogenetic genus, as we now know—occurred over much of Britain at virtually the same moment of Avonian time, since there is no reliable standard by which it can be dated.

Even in the South-Western Province the distinction between an Upper Caninia and a Lower Seminula zone is in most localities not feasible, since the limestones in which *Lithostroton* first appears are clearly the product of phasal changes marked by the replacement of shallow-water oolites and calcite-mudstones by coarse-grained open-sea "standard" crinoidal limestones; and the incoming of *Lithostroton* is an incident in a spectacular re-establishment of a rich coral and brachiopod fauna. Moreover, where the composite C_2S_1 zone as a lithological unit is most typically and thickly developed, lithostrotonids appear at abnormally low horizons, the base of the Lower Seminula zone (defined by that appearance) lying at rather less than 100 feet above the mid-Avonian lagoon phase. It is to be anticipated that, in suitable circumstances, *Lithostroton* could appear sufficiently early to obliterate the conventionally defined Upper Caninia zone altogether. (Compare Reynolds & Vaughan, 1911, p. 367.)

The effect of Dixon's stratigraphical analysis (Dixon & Vaughan, 1911, p. 542) was a partial rejection of the palaeontological criterion for separating the Clevedonian from the Kidwellian stage (so that incidentally the names fell into desuetude). By implication Dixon insisted on a facies definition of Avonian stages in his demonstration that the major lithological cycles in the South-Western Province were consequent upon appreciable earth-movement. He presented a strong case for diastrophism to be regarded as a principal ground for the separation of the Upper from the Lower Avonian stage, and his views have since been generally accepted, though they cause an unfortunate splitting of the Caninia zone.

These variations in classification are clearly artificial in the sense that the stage and zonal divisions are established at locally convenient phasal boundaries and do not reflect an absolute time-scale represented in a series of sediments of which the thicker developments are substantially continuous. Thus the mid-Avonian lagoon phase characterizing the base of the Upper Caninia zone in much of the South-Western Province is in detail transitional from the underlying Caninia Oolite, and contains oolitic layers virtually indistinguishable lithologically from the massive oolite beneath. It is a conveniently identifiable datum in a succession of lithological changes; but, as Dixon himself recognized, it by no means follows that it is everywhere of the same age.

Nevertheless, the significance of the mid-Avonian stratigraphical nomenclature adopted in the South-Western Province is not altogether spurious. It reflects real changes in lithology, which, over the comparatively small area of the Province, were approximately synchronous: there can be little doubt, for instance, that the Caninia Oolite (the Gully Oolite) of the Avon section is to be correlated with the Caninia Oolite of the Vale of Glamorgan and of Gower. On Dixon's exposition, it is then proper to regard the top of the Lower Avonian stage in the South-Western Province as being defined by the Caninia Oolite (wherever that rock may be identified). Moreover, in terms of the succession named by Vaughan and revised by Dixon, the Oolite perforce belongs to the Lower Caninia zone, which was in the first instance specifically and explicitly designed to include the Oolite and has continued ever since consistently to include it despite other nomenclatural changes.

The conclusion that the Caninia Oolite is necessarily of uppermost Tournaisian age is not contingent: it could only be established by acceptable correlation of the Oolite with the appropriate beds of the Franco-Belgian succession, the Calonne and Vaulx limestones and part of the Waulsortian reefs. The general lack of fossils in the Oolite (*Michelinia* and primitive koninckophyllids are the only relatively common corals) makes difficult the recognition of its equivalents outside the South-Western Province* (compare Vaughan, 1915, pp. 20-23). Nevertheless the occurrence of goniatites in the Oolite of Gower (George & Howell, 1939), including forms comparable or identical with *Prolecanites discoides* (= *Protocanites lyoni*), *Muensteroceras inconstans*, and *Pericyclus kochi*, supplemented by the occurrence of goniatites in the Upper Caninia zone at no great distance above the Oolite (George & Ponsford, 1935), including *Muensteroceras euryomphalum* and *Merocanites cf. compressus*, indicates an age very close to that of the uppermost Tournaisian beds of Belgium (Delépine, 1940, p. 19); and it may be concluded that the upper limit of the Lower Avonian stage broadly coincides with that of the Tournaisian.

The Caninia Oolite is in its facies limited, however, to parts of the South-Western Province. Using the succeeding Nassauian unconformity (at its climax) as a convenient chronological datum, and thus extending Dixon's initial thesis, Hudson & Dunnington (1944, p. 212) have argued that the *humerosa* beds of the Central Province, which underlie the unconformity, equate with the Oolite. This may well be the case (though *Plicatifera humerosa* has not yet been recorded from the South-Western Province): the consequent zonal deduction is that the *humerosa* beds, hitherto regarded as falling into the Upper Caninia zone, belong to the Lower. An obvious complication ensues, however, since the *humerosa* beds cannot then correlate with the *sublaevis* Oolite of Belgium unless the Caninia Oolite is

* The correlation of the oolites of the Caninia zone of the Avon Gorge and the North Mendips was itself an instance of this sort of difficulty, even though the two areas are close together (Reynolds & Vaughan, 1911, p. 348).

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younger than the limestones of Calonne and Vaulx and is to be referred to the Viséan, the base of which would thus lie at a higher horizon than the base of the Upper Avonian.

VI. THE CANINIA OOLITE IN THE SOUTH-WESTERN PROVINCE

Facies changes present difficulties in correlation which are well borne out in the zonal obscurities of the Avonian succession in the Forest of Dean. Even more difficult is the problem of interpreting a stratigraphical change when the facies succession apparently remains constant, but there are grounds for suspecting diachronism as the sediments are traced laterally.

The general similarity of the Tournaisian zonal succession in the Avon Gorge and the Mendips to that of Glamorgan and South Pembrokeshire is so close that there is little doubt of the respective zones being equivalent in time no less than in lithology: this follows from their having been deposited along a strike sub-parallel with the major shoreline of St. George's Land to the north. When, however, that shoreline is approached across the strike, anomalous variations in thickness and fauna cast doubt on the possibility of the facies units being everywhere of comparable age. This is well illustrated by the occurrence of oolites above the Lower Limestone Shales.

If the Lower Limestone Shales are regarded as a convenient lowest subdivision of the Tournaisian (though this assumes what has not been proved and what is likely to be true only in a general sense), the "Caninia Oolite" as it is traced northwards along the East Crop and westwards along the North Crop in South Wales appears to retain both its stratigraphical position immediately beneath C_2 and its general lithological character. At the same time, the beds between it and the Lower Limestone Shales become progressively thinner until, on the North Crop, they are reduced to some sixty feet near Abergavenny and less than twenty feet in the Vale of Neath. It is not easy to suppose that the crystalline dolomites of this remnant can be regarded as the sedimentary equivalents of 800-900 feet of the Zaphrentis and Lower Caninia zones of the southern outcrops in South Wales. There is, however, no lithological evidence of discontinuity in the succession on the North Crop, and no sign of an erosive junction between the "Caninia Oolite" and the underlying dolomites. In all probability, therefore, the oolite in this ground is older than the true Caninia Oolite of Gower or the Avon Gorge: significantly it contains a number of fossils, including *Camarotoechia mitcheldeanensis*, *Leptaena*, *Spirifer tornacensis* and pustulose productids which, though not completely diagnostic, possess the aspect of an assemblage more typical of the Zaphrentis zone than of the Caninia zone, and strengthen the doubts cast upon a correlation which is solely based upon lithological similarity. Since the Lower Limestone Shales beneath the dolomites are reduced to a quarter or less of their thickness in the southern outcrops, it is possible that the lateral changes of facies are yet more radical.

VII. "STANDARD" LIMESTONES OF THE UPPER TOURNAISIAN

When such difficulties arise in the comparatively small area of the South-Western Province it is only to be expected that facies changes more or less effectively prohibit correlation between the South-Western Province and the ground to the north. There is no palaeontologically acceptable evidence to establish the precise equivalence of the individual regional units of the Zaphrentis and Lower Caninia zones of the Avon with any of the subdivisions established by Hudson and Parkinson (1926, 1936) in Yorkshire and Lancashire. Even in the richly fossiliferous crinoidal "standard" limestones of Glamorgan the massive calcareous lithology is appreciably different from that seen in the Chatburn limestones and the Haw Bank limestones; while the recurrent shale facies of the Central Province is virtually unrepresented in the South-Western Province. In a general sense the zaphrentid fauna of the two regions is of broadly uniform aspect, but the richer assemblage of corals found in the north serves only to reveal the relative poverty of the southern assemblage.

The brachiopods also differ between the two Provinces: for instance the characteristic *Dictyoclostus teres* of the north has not yet been recorded from the south where it may not be present. Moreover there are certain anomalies in distribution, *Plicatifera humerosa* and *Chonetes destinezi* being found together, whereas, if the *humerosa* beds are the equivalent of the Caninia Oolite and reliance is to be

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placed in the productid as a zonal form, they should be found in sequence. Still farther north the evidence for the existence of the Zaphrentis zone is virtually nil, since it is to be found in the abnormal cementstones: the lowest recorded horizons in Cumberland and Westmorland are of Caninian age if reliance can be put upon the special fauna which includes *Camarotoechia proava* and *Dictyoclostus teres*.

In Scotland there is no acceptable evidence of any kind suggesting the occurrence of the Zaphrentis zone and only dubious evidence of the Lower Caninia zone. This is not to say that they are not present but only that the cementstone facies, unfossiliferous so far as corals and brachiopods are concerned, has as yet yielded forms—mainly algae—which require much greater examination before they can provide grounds for correlation.

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DISCUSSION

G. G. DELÉPINE fait observer que la présence de *Spirifer tornacensis* dans l'oolithe supérieure d'âge viséen de la région de Bristol s'explique par la permanence du faciès; le même fait s'observe en Belgique, où *S. tornacensis* se retrouve au dessus de la limite entre Tournaisien et Viséen quand le faciès crinoïdique se maintient sans changement à ce moment de la sédimentation.

T. S. WESTOLL said that the suggestion that the thin development of the Lower Carboniferous in Scotland may be explained on the supposition that part of the Scottish Upper Old Red Sandstone may perhaps be of early Avonian age does not seem to be compatible with the fossil vertebrates of the Upper Old Red Sandstone, either in Scotland or in England. For example, the *Bothriolepis-Holoptychius-Phyllolepis* fauna makes its appearance in Dura Den within c. 150 ft. of the conformable junction of the Carboniferous; this is a fauna known from Famennian strata. There is no doubt that the accepted Old Red Sandstone-Carboniferous boundary in Scotland is arbitrary, however, and much of importance remains to be done. Such work will certainly require a most careful study of facies-differences.

T. N. GEORGE, replying, said that in the Midland Valley of Scotland there is no certain evidence of any of the Avonian zones below the Dibunophyllum Zone, though doubtless some or all of the lower zones must be represented by sediments. The Cementstones series, without corals and brachiopods, is appreciably thinner than equivalent beds farther south, and is much thinner than presumed equivalents in the South-Western Province. If the Old Red Sandstone is of Devonian age as proved by the occurrence of *Phyllolepis* and *Holoptychius*, then the Cementstone series may contain evidence of hitherto unsuspected breaks.

FAUNISTIC SUBDIVISIONS AND CORRELATION OF THE LOWER CARBONIFEROUS OF THE U.S.S.R.

By L. S. LIBROVICH
U.S.S.R.

ABSTRACT

The lower boundary of the Carboniferous system within the U.S.S.R. corresponds to the base of the Malevko-Muraevnia beds in the Moscow Basin, of the Novotroitsk zone in the Donetsk Basin, of the strata with a fauna of the Etroeungt type or of the beds with *Synwocklumeria* in the Urals and in Central Asia, of the Aabysev zone in the Kuznetsk Basin, etc.

In the Lower Carboniferous of the U.S.S.R. the boundary of the Tournaisian and the Viséan is at the base of the beds with an abundance of *Productus humerosus* J. Sowerby in the marine brachiopod facies of the Urals and Central Asia, and at the base (or near the base) of the coal-bearing deposits of the southern part of the Moscow Basin and the western slope of the Urals, etc.

There are no grounds sufficient for regarding the boundary of the Viséan and the Namurian as the upper boundary of the Lower Carboniferous.

A conspicuous incoming of new faunal (and floral) elements is observed at the base of the *Reticuloceras* zone and at the base of the Bashkirian strata of the Urals and their analogues (appearance of *Staffella antiqua* Dut., coarsely costate *Choristites*, etc.). However, this boundary, passing within the Namurian stage, the Serpukhovian series of the Lower Carboniferous of the Moscow Basin, etc., is not suitable for separating the Lower from the Middle Carboniferous.

An argument in favour of drawing the boundary of the Lower and Middle Carboniferous between the Namurian and the Westphalian, as it is most widely accepted in the U.S.S.R.—that is, at the base of the Carboniferous series of the Donetsk Basin, at the base of the Upper Bashkirian beds of the Urals, etc.—is presented by the substantial entry of a new fauna above this boundary (appearance of the first fusiform Fusulinidae—*Profusulinella*—the first typical, finely costate *Choristites*, typical *Gastrioceras*, etc.).

DISCUSSION

A. LAMONT observed that the incoming of complex foraminifera like *Archaeodiscus karreri* marks off the S Zone of the Avon Gorge at Bristol from the Caninia Oolite below which has forms of an Upper Devonian simplicity in number of camerae, etc. Much the same break occurs in Russia, and this deserves further investigation.

J. S. LEE remarked that the same fauna as that discussed by the author is characterized in China by *Profusulinella*, which occurs also in the U.S.A. and is traceable to the Alpine region. He wondered how the fusulinid fauna originated.

CORAL ZONES IN THE UPPER PALAEOZOIC OF THE URALS

By I. I. GORSKY

U.S.S.R.

ABSTRACT

1. The best studied deposits of the Urals with regard to coral faunas are the Upper Palaeozoic deposits, in which several zones are distinguished by them: three in the Middle Carboniferous, two in the limestone facies of the Upper Carboniferous and Lower Permian, and two in the areno-argillaceous facies of the Lower Permian.

2. The coral fauna of Pz₃ of the Urals is a local one, which has developed from an Upper Viséan fauna. It is characterized by a profusion of descendants of *Caninia juddi* Thomson, as well as of colonial corals of the genera *Diphystrotion*, *Orionastraea*, *Cystophora*, and *Thysanophyllum*, which impart an archaic appearance to the fauna. Highly organized *Protowentzelella*, *Wentzelella*, and *Lonsdaleiastraea* constitute an insignificant part of the fauna and appear later than in other areas. *Waagenophyllum* and *Polythecalis* are absent.

3. A comparison of the coral faunas of Pz₃ of the Urals with faunas of other countries shows that (a) the coral fauna is of restricted importance in correlating sections represented by different sediments; (b) in comparing the coral faunas of any particular regions the nature of the sediments should be considered; (c) within a given region the fauna belonging to one facies is of the same type and makes possible a precise correlation to a zone or horizon, but in studying the coral fauna one should adhere to a narrow interpretation of species.

ONE of the better studied groups, rivalling in this respect the Foraminifera and Brachiopoda, are the corals of the Upper Palaeozoic formations of the western slope of the Urals.

THE CORAL FAUNA OF THE MIDDLE CARBONIFEROUS: GENERAL CHARACTERISTICS

The coral fauna of the Middle Carboniferous, though a further stage of the development of the coral fauna of the upper part of the Lower Carboniferous, possesses readily detectable peculiarities which permit exact distinction between the two. Of these peculiarities the following may be noted. The Middle Carboniferous coral fauna is destitute of such genera as *Palaeosmia* and *Dibunophyllum*, so characteristic of the Lower Carboniferous; others occur as single, rare forms, such as, for instance, *Lithostrotion*, which is extremely frequent in the Lower Carboniferous. Completely absent are the groups of *Lonsdaleia floriformis* Mart. and *Lonsdaleia duplicata* Mart., which are characteristic of the Lower Carboniferous, and many species of the genera *Caninia*, *Koninckophyllum*, *Diphyphyllum*, *Zaphrentis*, etc.

Some groups of species and some genera which existed in the Lower Carboniferous but which played no important part in the composition of its fauna underwent intense development in the Middle Carboniferous. Such is the group of the Lower Carboniferous species *Caninia juddi* Thom., and the genera *Fischerina*, *Corwenia* and especially *Bothrophyllum*, the latter being probably the most common genus among the Middle Carboniferous corals of the U.S.S.R.

The Middle Carboniferous of the Urals is also characterized by the profusion of species of the genus *Caninia*, rivalling in frequency the genus *Bothrophyllum*. Finally, new forms which develop in the Middle Carboniferous are *Multithecopora*, *Timania*, *Pseudotimania*, *Lithostrotionella*, *Cystophora* (absent in the Urals), *Lytvophyllum*, *Koninckophyllum* and *Lophophyllidium*.

Despite such great differences between the Lower and Middle Carboniferous coral faunas, their genetic relations are quite obvious, and the Middle Carboniferous fauna presents but a further stage in the development of the coral fauna of the Lower Carboniferous. The close affinity between them is

apparent not only from the existence of common genera, but also from new forms dating from the Middle Carboniferous which have their ancestors in Lower Carboniferous species and genera.

DEVELOPMENT OF THE CORAL FAUNA IN THE MIDDLE CARBONIFEROUS

On a somewhat more detailed inspection of the Middle Carboniferous coral fauna from the viewpoint of its changes in time within the limits of the Middle Carboniferous and in space within the boundaries of the western slope of the Urals, some statements may be made which will be helpful in realizing the stratigraphical importance of corals.

Let us consider more explicitly the faunas of two regions, those of Kizel-Chusovaia and Bashkiria, to which belong the great majority of Middle Carboniferous corals described. These faunas each contain several representatives of the genera *Chaetetes*, *Caninia*, *Bothrophyllum*, *Campophyllum*, and *Koninckophyllum*; common to both, yet represented by single specimens, are *Pseudotimania*, *Lophophyllidium*, *Lithostrotion*, *Lithostrotionella*, *Lytvophyllum* (erected by T. A. Dobrolyubova for corals similar to *Thysanophyllum*, but having a columella), and *Corwenia*.

The genus *Hapsiphyllum* has been found in the Kizel-Chusovaia region, but the genera *Multi-thecopora*, *Cladochonus*, *Zaphrentis*, *Lophophyllum*, *Arachnolasma*, *Fischerina*, *Orionastraea*, and *Dibunophyllum* (?) in the Bashkirian only.

Hence, the Bashkirian fauna is considerably the richer in generic composition. It must be remembered, however, that the above genera are mainly represented by one species and few or even single specimens, and their presence or absence in the record may to a considerable degree depend on chances of collecting.

Still greater divergences are observed in the specific composition. Thus the Bashkirian fauna is apparently totally devoid of a peculiar group of small *Caninia* (group of *Caninia irinae* Gorsky) which is widely distributed in the lower part of the Middle Carboniferous of the Kizel-Chusovaia region. The group of *Caninia remotetabulata* Gorsky, proper to the Kizel-Chusovaia region, is also lacking, whereas that of *Caninia nalivkini* Gorsky, absent in the Kizel-Chusovaia area, occurs in great numbers and is represented by several species. A species of the genus *Caninia*, abundantly represented in both regions, is the unique species *Caninia mutafii* Gorsky.

Another essential difference is the smaller number of representatives of the genus *Bothrophyllum* in the Bashkirian fauna, while in the Kizel-Chusovaia region it is abundant and much more varied in specific composition.

A third difference is the occurrence in the Bashkirian fauna of an undescribed subgenus not encountered in the Kizel-Chusovaia area, as well as the great frequency in the former of a variety of *Lytvophyllum tshernovi* Soschk., which is rare in the Kizel-Chusovaia region.

These substantial differences in generic and specific composition of the faunas—besides chance and imperfection of collecting, which are of importance only for rare genera and species—may be explained (a) by asynchronism of the two faunas, and (b) by different facial conditions.

Indeed, the faunas are asynchronous. The effect of this factor is particularly evident on analyzing the faunas of the lower part of the Middle Carboniferous of the two regions. The Middle Carboniferous of Bashkiria is divided into three series, C_2^a , C_2^b , C_2^c ; the Middle Carboniferous of the Kizel-Chusovaia region is also composed of three series, C_2^1 , C_2^2 , C_2^3 , all asynchronous.

The lowermost part of the Bashkirian Middle Carboniferous is absent in the Kizel-Chusovaia region, while the well-developed and richly coralliferous Bashkirian strata (horizon C_2^b) apparently only partly possess analogues in the lower series (C_2^1) of the Kizel-Chusovaian Middle Carboniferous. In other words, the Bashkirian profile of the Middle Carboniferous includes an older part than that of the Kizel-Chusovaia region.

Apparently, this circumstance may partly explain the difference in composition of the coral fauna, namely, the presence in the Bashkirian fauna of such genera as *Dibunophyllum* (unique specimen) and *Fischerina*, large divergences in specific composition of the genus *Campophyllum*, and the frequent

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occurrence of *Lithostrotion*—all archaic characters pointing to the proximity of the Lower Carboniferous fauna.

However, the explanation by asynchronism does not hold on comparing the faunas of the upper parts of the profile, which were apparently synchronous in their formation. It is true that the remains of corals might have been collected from incompletely synchronous horizons, but in that case such differences are inconceivable as the small number of representatives of the genus *Bothrophyllum* in the Bashkirian fauna, the very wide divergences in specific composition of the genus *Caninia*, and differences of generic composition.

These differences are in all probability to be explained not only by asynchronism of respective coral faunas, but also by different facial conditions which have affected the characters of the rocks. The whole profile of the Middle Carboniferous of Bashkiria as regards the coral localities is represented exclusively by carbonate rocks mainly composed of pure limestones, while in the Kizel-Chusovaia profile a considerable part ($\frac{1}{3}$ — $\frac{1}{2}$) is built up of rocks with a large admixture of terrigenous material, or entirely consists thereof. Such are the rocks of the series C_2^2 —marls, shales, sandstones, clayey limestone, etc.

As regards the changes of the coral fauna within the limits of the Middle Carboniferous, that of the lower horizon (C_2^1) in the Kizel-Chusovaia region is characterized by the presence of groups of small *Caninia* (*Caninia irinae* Gorsky), the smaller number and rare occurrence of representatives of the genus *Bothrophyllum*, the rather wide distribution of the genus *Campophyllum* and the appearance of a new genus, as well as of the group of *Koninckophyllum riphaeicum* Gorsky (remarkable for the simplicity of structure of its central zone).

In the middle horizon (C_2^2) the number of small *Caniniae* notably decrease till their complete disappearance with corresponding increase of that of the genus *Bothrophyllum*. The group of *Koninckophyllum riphaeicum* Gorsky continues to develop, and a few colonial corals appear belonging to the genera *Lithostrotionella* and *Lytvophyllum*.

The upper horizon (C_2^3) is characterized by a profusion of representatives of the genus *Bothrophyllum*, which frequently crowd the limestone and are varied in species, and by the presence of large *Caninia*, part of the trend of development from the Lower Carboniferous *Caninia juddi* Thom. to the group of *Caninia kokscharowi* Stuck., which is abundant in the Upper Carboniferous and Lower Permian limestones of the western slope of the Urals.

The Bashkirian Middle Carboniferous is also divided into three horizons. The lower, C_2^a , might even be partly referred to the Namurian; it is poor in coral remains. The middle horizon (C_2^b), or Bashkirian Beds, contains a rich coral fauna. There appear the genera *Multithecopora* and *Cladochonus* of the Tabulata, and, of the Rugosa, the new genus noted above, numerous species of the genus *Campophyllum* (particularly characteristic is the peculiar *Campophyllum contortulum* Gorsky), the new subgenus mentioned on p. 45, and various genera of colonial corals: *Fischerina*, *Lithostrotion*, *Orionastraea*, *Lithostrotionella* and *Lytvophyllum*, however, are represented by a small number of specimens, save for the last-named genus. The upper series (C_2^c) is characterized by the appearance of the group of *Caninia nalivkini* Gorsky, of a small quantity of specimens of *Bothrophyllum*, and of the genus *Kionophyllum*, and by the abundance of the new subgenus just mentioned.

COMPARISON OF THE CORAL FAUNA OF THE MIDDLE CARBONIFEROUS OF THE URALS WITH CORRESPONDING FAUNAS OF OTHER REGIONS

The question may arise: if the coral faunas of the Middle Carboniferous of the Urals differ so strongly from each other, the difference between the faunas of the Urals and those of other regions may be so great as to render any comparison impossible; in other words, whether the Uralian fauna is strictly local and unfitted for any stratigraphical and palaeogeographical applications which extend beyond the boundaries of the western slope of the Urals.

To solve this problem, the fauna of the Urals must be compared with others, but only the Moscow

and, in part, the Donetsk basins, and to a certain degree China, may be drawn into comparison, the coral faunas of other regions being so far completely unexplored.

On comparing the fauna of the Urals with that of Moscow we are led to the following statements. The former in its generic composition is considerably the richer—24 genera against 17. Genera common to both are *Chaetetes*, *Bothrophyllum*, *Dibunophyllum*, and *Lithostrotionella*. The Moscow fauna is characterized by the profusion of colonial corals and representatives of the genus *Bothrophyllum*, while in that of the Urals colonial corals are rare, with the exception of *Lytvophyllum*, which is completely absent in the Moscow fauna. Further, no specimen of any species of *Caninia* has been recorded from the Moscow Middle Carboniferous, whereas species of this genus in the Urals are manifold and varied. It may be that this depends on different conceptions of the range of the genus *Caninia* by authors, but at any rate the general aspect of the fauna from each of the two regions is different.

It must be recognized that both the coral faunas, while of undoubted Middle Carboniferous age, are peculiar, with little resemblance between them, though the corals of the Urals, like those of Moscow, well characterize separate horizons.

The Ural fauna bears distinct indications of affinity only with the Lower Carboniferous of that area, for example, in the genera *Chaetetes*, *Cladochonus*, *Amplexus*, *Hapsiphyllum*, *Zaphrentis*, *Caninia*, *Bothrophyllum*, *Campophyllum*, *Lophophyllum*, *Koninckophyllum*, *Lithostrotion*, and *Dibunophyllum*.

On comparing the fauna of the Urals with that of the Donetsk basin, only a very faint resemblance may be seen, just as with the Moscow fauna or even less. The same is true between the coral faunas of the Donetsk and Moscow basins. From the former, despite its variety, only four species have been recorded common to the Moscow fauna (in the case of Urals and Moscow, six). Moreover, the general composition of the Donetsk fauna differs from that of the Urals by the considerable profusion of colonial corals, by the diversity of simple corals with a columella, among which numerous new genera have been described, and by the small number and little variety of *Caninia*.

With the Chinese fauna the Urals have five species in common. It is interesting to note that the Chinese fauna contains very rare representatives of such a characteristic coral of the Middle Carboniferous as the genus *Bothrophyllum*, whereas both the Chinese and Ural faunas include a group of peculiar *Koninckophyllum* with faintly developed columella.

A brief comparison of the Middle Carboniferous faunas of the four regions (Urals, Moscow and Donetsk basins, and China) shows that the coral fauna of any of them is remarkable for its considerable variety despite the small number of common species which make them comparable only in their general aspect.

Were we to take the coral fauna of any region and analyze it according to stratigraphical horizons, we should readily see that the fauna of each horizon (if in sufficient quantity) possesses characteristic features distinctly expressed. Hence, we must recognize that corals (where in sufficient profusion) are reliable indices in stratigraphy, fitted for faunistic characteristics or fractional stratigraphical divisions, but only within more or less narrow limits of one and the same geological region and the same facial conditions.

THE CORAL FAUNA OF THE UPPER CARBONIFEROUS AND LOWER PERMIAN LIMESTONES

On the western slope of the Northern and part of the Central Urals, and on the Ufa plateau and a part of the western slope of the Southern Urals, the Middle Carboniferous deposits are overlain by a powerful series of limestones all of which were first referred to the Upper Carboniferous. Nowadays the upper part of this series, beginning with the appearance of *Parafusulina lutugini* Schellw., is assigned to the Lower Permian*.

Thus the coral faunas of the limestones of the Upper Carboniferous and Lower Permian have been

* D. M. Rauser-Chernousova draws the boundary of the Permian lower, under the beds with *Pseudofusulina anderssoni* Schellw. V. E. Rujentsov assigns to the Permian still lower horizons with *Pseudoschwagerina*.

studied from a wide area of the western slope of the Urals, from the right-hand tributaries of the Pechora (Podcherem, Stchugor, etc.) as far as the latitude of Sterlitamak.

Comparing all this abundant material we note first of all the unity of the fauna, not only manifest in its generic composition, but also in the profusion of common species. Thus, species of the genera *Orionastraea*, *Cystophora*, *Tschussowskenia*, *Thysanophyllum*, *Wentzelella* and *Lonsdaleiastraea*, erected by T. A. Dobrolyubova, have been found in all the faunas.

The comparison of data from the Kizel region, the Ufa plateau and Sterlitamak shows that the assemblages of the coral fauna, determined first by T. A. Dobrolyubova for the Ufa plateau, hold very steadily and distinctly for those other areas of development of the limestone series of the Upper Carboniferous and Lower Permian.

It must be borne in mind that T. A. Dobrolyubova stated the following four horizons:

(1) The lowermost, with a profusion of massive colonies of *Thysanophyllum perpastum* Dobr., *T. cystosum* Dobr., and *Campophyllum* cf. *amplexoides* Stuck. Thickness about 44 m.

(2) Upward there follow limestones with *Orionastraea campophylloides* Dobr., *Cystophora biseptata* Dobr., and all the species of the genus *Thysanophyllum*, save for typical *Thys. perpastum* Dobr. Thickness 124-130 m.

(3) Further upward, limestones with all the species of the genus *Orionastraea*. The species *O. campophylloides* Dobr. and *Cystophora biseptata* Dobr. occur more seldom than in the underlying horizons. Thickness about 140 m.

(4) The uppermost horizon is characterized by *Cystophora wischeriana* Stuck. and representatives of the genus *Protolonsdaleiastraea*.

To still higher strata T. A. Dobrolyubova refers limestones with *Lonsdaleiastraea*.

If the above sequence is compared with the distribution of the coral fauna in the Kizel region, it will be readily seen that the two lowest horizons, of which the lowermost plays no independent part because of the scarcity of its fauna, correspond in the composition of its fauna and in its thickness to horizon C₃² of the Kizel region*. Indeed, in the latter horizon the following have been recorded: *Caninia longisepta* Greck., *C. sp. nov.*, *C. verneuili* Stuck. var. nov., *Timania schmidtii* Stuck., *T. schmidtii* Stuck. var. nov., *Campophyllum schrenki* Stuck., and the colonial corals *Lithostrotionella* (?) sp. nov., *Tschussowskenia captiosa* Dobr., *Cystophora biseptata* Dobr., *Thysanophyllum perpastum* Dobr., *T. aseptatum* Dobr. var. nov., *T. cystosum* Dobr. var. *major* Dobr., and *Carcinophyllum indigae* Stuck.

The list of corals for the lower part of horizon P₁¹ in the Kizel region is as follows: *Sinophyllum* sp. nov., *S. sp.*, *Laccophyllum* sp. nov., *Caninia* cf. *kokscharowi* Stuck., *C. kokscharowi* Stuck. var. nov., *C. lonsdalei* Keys., *C. sp. nov.*, *C. verneuili* Stuck., *C. mylensis* Stuck., *C. sp.*, *Timania schmidtii* Stuck., *T. schmidtii* Stuck. var. nov., *Diphytrotion* spp. nov., *Lithostrotion* (?) sp., *Orionastraea campophylloides* Dobr., *O. stuckenbergi* (Gerass.), *O. solida* Stuck., *O. solida* Stuck. var. nov., *O. brevisseptata* Dobr., *O. brevisseptata* Dobr. var. nov., *Lithostrotionella* sp. nov., *L. (?) sp. nov.*, *Tschussowskenia captiosa* Dobr., *Cystophora biseptata* Dobr. var. nov., *C. (?) sp. nov.*, *C. monoseptata* Dobr., *C. monoseptata* var. 2 Dobr., *C. cf. monoseptata* var. 3 Dobr., *C. monoseptata* var. 4 Dobr., *C. monoseptata* Dobr. var. nov., *C. wischeriana* (Stuck.), *C. wischeriana* var. nov., *C. sp. nov.*, *Thysanophyllum aseptatum* Dobr., *T. aseptatum* Dobr. var. nov., *T. cystosum* Dobr., *T. cystosum* var. *major* Dobr., *Protowentzelella* sp. nov., *Wentzelella* spp. nov., and *Lonsdaleiastraea* (?) *complexa* Dobr.

The fourth horizon separated by T. A. Dobrolyubova apparently also fits into the limits of horizon P₁¹ of the Kizel region, to judge from the occurrence in it of *Cystophora wischeriana* (Stuck.).

Thus, from the brief comparison of the fauna given above, the coral fauna of the Upper Palaeozoic limestone series of the Ufa plateau and the Kizel region appears to be of one type, while not

* The only corals in horizon C₃² are *Cyathaxonia* sp., *Caninia kokscharowi* Stuck. var. *tschussowensis* Greck., and *Lophophyllum* sp., so that it cannot be sufficiently characterized by its coral fauna. In profiles drawn by T. A. Dobrolyubova the underlying limestones were also poor in corals.

only does that type persist but the age sequence of assemblages also remains the same throughout.

Hence it may be stated that over the whole enormous area of the western slope of the Urals, wherever the limestones of the Upper Carboniferous and Lower Permian are distributed, one type of coral fauna occurs in which two well defined assemblages may be delineated.

On comparing the fauna of the Upper Carboniferous and Lower Permian of the Urals with the corresponding faunas of other regions of the U.S.S.R. or foreign countries very little resemblance is seen, just as in the case of the Middle Carboniferous fauna.

Conditions for comparison with the Moscow basin are unfavourable, the coral faunas there occurring in the lower part of the Upper Carboniferous, whereas in the Urals the coral fauna belongs to the upper part of the Upper Carboniferous and Lower Permian.

In the Donetsk basin, according to V. D. Fomitchev, the coral fauna also belongs to relatively low horizons of the Upper Carboniferous—all the simple corals have been described as new species, while of the colonial forms only *Polythecalis* and *Lonsdaleiastraea* are named from the Upper Carboniferous (series O).

The Samara bend is also unfitted for comparison, its horizons with corals being older than the coral horizons of the Urals: the species truly common are only *Caninia lonsdalei* Keys. and *C. verneuili* Stuck.

In the corresponding faunas of foreign countries, some resemblance may be traced in the generic composition of the Permian faunas of China, but the general type and the specific composition of the Ural and Chinese faunas have little in common, which is rather to be explained by the younger age of the Chinese fauna and by its belonging to another zoogeographic province.

The coral assemblage of horizon C_3^2 corresponds approximately to the zone with *Pseudoschwagerina*; while the next, that of the Lower Permian, corresponds with the lower part of the zone with *Parafusulina lutugini* Schellw.

Approximately the same is observed with regard to the Brachiopoda. Strata including the coral assemblage of horizon C_3^2 correspond to a part of the profile with the so-called Uralian assemblage of brachiopods, namely, with the lower sub-assemblage characterized by a rich and varied brachiopod fauna: *Productus genuinus* Krot., *P. kutorgae* Krot., *P. transversalis* Tschern., *P. pseudomedusa* Tschern., *P. jakowlewi* Tschern., etc., *Spirifer lyra* Kut., *S. holzapfeli* Tschern., *Pseudomartinia*, *Martiniopsis*, *Wellerella*, *Pugnax*, etc.

Strata with the coral assemblage of horizon P_1^1 correspond to the lower part of the strata with the Artinskian assemblage of brachiopods, with *Spiriferella saranae* Vern., *Productus stuckenbergi* Krot., *P. pseudoaculeatus* Krot., *P. orientalis* Fredericks, *P. ufensis* Fredericks, *P. gruenewaldti* Krot., *P. uralensis* Lich. (= *P. uralicus* Tschern.), etc.

A powerful series of limestones, whose deposition lasted throughout the Upper Carboniferous and part of the Lower Permian epochs, represents the sediments of one and the same basin with comparatively little varying conditions of habitat yet within definite limits and along definite trends.

In all probability these circumstances account for the unity of faunas occurring in these series. Only a sudden variation of physiographic conditions and the replacement of limestone deposits by arenaceous-clayey ones brought about greater changes in the coral fauna.

THE CORAL FAUNA OF THE ARENACEOUS-CLAYEY FACIES OF THE UPPER CARBONIFEROUS AND LOWER PERMIAN

The arenaceous-clayey series originally referred to the Artinskian contains a peculiar coral fauna. It has been lately established that arenaceous-clayey deposits of the "Artinskian" type are distributed not only in the Lower Permian but also in the Upper Carboniferous and even in the upper part of the Middle Carboniferous. There is so far no complete and clear idea of the true age of the "Artinskian" arenaceous-clayey deposits at different parts of the western slope of the Urals, and the stratigraphy of these series is still in process of establishment; nevertheless it may be noted that, for the southern part of the Northern Urals and the northern part of the Central Urals, say, from the

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latitude of the Kolva to that of the town of Chusovoy, the arenaceous-clayey deposits are younger than the Lower Permian limestones and are thus of Permian age.

Southward, along the Ufa amphitheatre, the gradual substitution of the limestone facies of the Lower Permian, Upper Carboniferous and the upper parts of the Middle Carboniferous by the arenaceous-clayey terrigenous facies takes place.

Still farther southward, to the south of the Ufa plateau and approximately as far as the latitudinal course of the river Belaia, the profile of the Lower Permian and, south of the Belaia, the profile of the Lower Permian and the Upper, Middle and parts of the Lower Carboniferous are represented by arenaceous-clayey rocks interbedded with limestones.

The coral fauna of the arenaceous-clayey series is characterized by the prevalence of small, simple corals, frequently of irregular form, with an extraordinary development of some features, very variable, with indistinct specific characters. Representatives of the genera *Tachylasma*, *Stereolasma*, *Lyivolasma*, *Lopholasma* and others of the family Streptelasmidae, as well as of the genera *Amplexus* (*Amplexocarinia*), *Cyathaxonia* (*Cyathocarinia*), *Plerophyllum*, etc., are frequent.

E. D. Soshkina points to the presence in the arenaceous-clayey series of two assemblages of a coral fauna, an older one with representatives of the family Streptelasmidae, and a younger with dominant Plerophyllidae.

There are so far no data for co-ordinating with each other the faunas of the arenaceous-clayey and limestone facies, but we may point to the fact, mentioned by E. D. Soshkina, that in the Northern Urals, in a profile of the Lower Permian, strata with *Wentzelella* overlie those including the older assemblage of the fauna of the arenaceous-clayey facies.

CONCLUSIONS

(1) In the Upper Palaeozoic of the Urals seven fairly distinctive coral assemblages may be separated (three assemblages in the Middle Carboniferous, two in the limestone facies of the Upper Carboniferous and Lower Permian, and two in the arenaceous-clayey facies).

In many profiles, in particular in the Upper Carboniferous and Lower Permian, corals occur in profusion and are remarkable for their good preservation and the small size of the corallites in colonies, thus permitting identification of comparatively small portions of the latter.

(2) Coral remains are not uniformly distributed throughout the whole profile, and the coral fauna does not immediately allow characterization of the whole section continuously, but only the separate parts of it in which the majority of the coral remains are concentrated, thus outlining the assemblages of the coral fauna.

(3) The coral fauna of the Upper Palaeozoic of the Urals, that of the limestone facies at least, represents, beginning with the upper part of the Lower Carboniferous, a fauna developing mainly *in situ* with a very faint influx of foreign forms. The main peculiarities of the Upper Carboniferous coral fauna existed from the Upper Viséan and the fauna is in the main local, differing considerably from faunas of corresponding age in other regions of the U.S.S.R. and foreign countries.

The main trends along which the coral fauna of the Urals developed, and its more characteristic peculiarities as a whole, are as follows. The profusion and variety of representatives of the genus *Caninia* present in their largest part the consecutive development of the group of *Caninia juddi* Thom., which was frequent in the upper part of the Lower Carboniferous of the Urals. This peculiarity is very sharply expressed in the Upper Palaeozoic fauna of the Urals in comparison, for instance, with that of the Donetz and, especially, the Moscow basins.

Another distinctive feature of the Upper Palaeozoic coral fauna of the Urals is the profusion in the Upper Carboniferous and Lower Permian limestone deposits of colonial corals belonging to *Diphytrotion*, *Orionastraea*, *Cystophora*, and *Thysanophyllum*, which give to the fauna a somewhat archaic aspect. More highly organized Lonsdaleidae, such as *Protowentzelella*, *Wentzelella* and *Lonsdaleiastraea*, constitute but a small part of the fauna and appear here later than in other regions. So far no representatives have been found of such genera as *Waagenophyllum* and *Polythecalis*.

A peculiarity of the Ural fauna in the limestone series is the scarcity of representatives of the family Streptelasmidae: by contrast, it is very richly represented in the fauna of the arenaceous-clayey series.

(4) It has been stated, from the comparison of the coral faunas of the Upper Palaeozoic of the Urals with those of other regions of the U.S.S.R. and foreign countries which are closely related or analogous in age, that in each region the faunas possess peculiarities and have very little in common with each other with regard to specific composition, while even within the boundaries of any one region separate areas occur which differ from one another in the origin of their fauna. This may be explained by the fact that corals are closely related to the habitat of the basin in which they live, and are dependent on it more than are other animals, the physiographical conditions of the basin thus being of determining importance for the composition and type of the fauna.

Hence, very important conclusions of a technical character may be drawn: (a) the coral fauna is of relatively little importance for the stratigraphic correlation of profiles of areas of unlike sediments, any deductions regarding age being possible to the exactness of about a stage. The greater the difference between deposits, the smaller the accuracy of deductions. (b) On comparing the coral faunas of separate regions or districts, the characters of the deposits must be very carefully considered in each profile; only then may conclusions be drawn as to the correlation of coral faunas in different profiles and serious errors be eliminated in using the data secured from the study of the coral faunas. From the comparison of the coral faunas of the Middle Carboniferous of the Urals and the Moscow and Donetsk basins we have learned how little in common have synchronous faunas which lived in basins with different physiographic conditions. (c) In contrast, within the boundaries of a region or district characterized by the unity of facial conditions, the coral fauna is of one type and holds more steadily throughout the area with the same type of deposits. In such cases not only is the unity of the fauna as a whole seen, but also a more or less uniform trend of its development in time within the limits of the whole basin.

Under such conditions, the possibilities of using the coral fauna for correlation are very large, and the degree of exactness and accuracy reaches the scale of an horizon or zone (when the coral fauna is sufficiently rich and densely distributed in the profile). The importance of the coral fauna for local zonal subdivisions is very great.

(5) The comparison of the coral faunas of various regions with faunas remarkable for their local origin, based upon the excessive development of local forms in each fauna and the very small number of common species, is mainly reduced to the comparison of the faunas as a whole, most frequently of their generic composition and to a lesser degree of groups of species. This implies special care and accuracy in assigning a coral to a genus, particularly in cases of a number of closely related genera, such as *Caninia*, *Caninophyllum*, *Bothrophyllum*, *Timania*, or other groups of associated genera. Henceforth we need accurate and careful generic diagnoses, while in using the literature available, a critical inspection is necessary of all the forms liable to be assigned to a related genus. Only under such conditions may one feel free from the wrong interpretation of resemblance or divergencies in coral faunas.

(6) While studying the coral fauna of any region or district characterized by the unity of facies of its sediments and, as has been stated, by its unity of type in composition and in the trend and rate of development, one must keep to a narrow interpretation of the species and avoid excessive generalizations which smooth out the minor stages of development. In studying a trend of development, all stages sufficiently well expressed with regard to morphology and chronology must be taxonomically noted.

If these conditions be observed, one may follow the development of any form or group of forms. On the other hand, they furnish grounds for determining the faunistic characteristics of a detailed stratigraphical profile and of a given area, and consequently for the construction, in combination with other groups, of a cumulative biostratigraphic section.

It must be taken into account that a narrow interpretation of a species puts further limits to the possibilities of correlating the faunas of separate regions or districts with other types of profile, and

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that stratigraphy based upon such narrow interpretations of species is of local importance (like any detailed stratigraphy) and is applicable only within the limits of the given region.

(7) The use of the narrow interpretation of species, especially in view of the homomorphism which is rather frequent among corals, implies a possibly complete knowledge of the ontogeny of each species with the aid of a series of slides. This will not only enable the morphologic peculiarities and their development in the given form to be deciphered, but also the genetic relations to be understood between allied forms, even though close relations between them are not always morphologically evident at different stages of development.

(8) As repeatedly noted, corals in their development are very closely connected with the habitat of their environment, while great changes of these conditions are reflected in the corals in a most rapid and decisive manner. However, we do not include any definite evidence regarding the importance and influence of various ecological factors on the life and development of corals. In this direction a large and interesting work on specially chosen objects is imminent, which uses a carefully elaborated technique. The evidence obtained in studying the effect of ecological factors will be at the same time exceedingly important for the question of the rate of variation in corals, and the resolution of these two problems has to proceed in very close touch with each other.

DISCUSSION

J. M. EDMONDS said that the work of the Russian palaeontologists and stratigraphers in the Carboniferous was greatly valued by workers in Britain and it was to be regretted that the authors of this and the previous papers were unable to be present. We had looked forward to informal contact with them and others working in contiguous fields, and hoped that they would realize that their work was appreciated.

G. G. DELÉPINE, regrettant que M. Gorsky n'ait pu lui-même nous exposer les résultats de son étude, y relève en particulier son observation que les polypiers ne peuvent guère être utilisés pour établir d'une manière sûre des corrélations quand il y a variation dans les faciès; et aussi la remarque de l'auteur au sujet de la nécessité de définir très exactement l'espèce, plus encore quand il s'agit de coraux.

КОРАЛЛОВЫЕ ЗОНЫ В РАЗРЕЗЕ ВЕРХНЕГО ПАЛЕОЗОЯ УРАЛА

И. И. ГОРСКИЙ

В настоящее время кораллы из верхнепалеозойских отложений западного склона Урала являются одной из наиболее изученных групп, соперничая в этом отношении с фораминиферами и брахиоподами.

2. КОРАЛЛОВАЯ ФАУНА СРЕДНЕГО КАРБОНА

А. Общая характеристика фауны

Коралловая фауна среднего карбона, хотя и представляет собою дальнейший этап развития коралловой фауны верхней части нижнего карбона, обладает, однако, легко уловимыми особенностями, позволяющими отчетливо различать эти две фауны друг от друга. Для фауны кораллов среднего карбона в целом по сравнению с нижнекаменноугольной коралловой фауной можно отметить следующие особенности. В среднекаменноугольной фауне отсутствуют столь характерные для нижнего карбона, рода, как *Palaeosmilia*, *Dibunophyllum*; другие встречаются в виде единичных редких форм — как например *Lithostrotion* — чрезвычайно часто встречающийся в нижнем карбоне. Совершенно отсутствуют характерные для нижнего карбона группы *Lonsdaleia floriformis* Mart. и *Lonsdaleia duplicata* Mart. и многие характерные для нижнего карбона видороды *Caninia*, *Koninckophyllum*, *Diphyphyllum*, *Zaphrentis* и др.

Усиленно развиваются в среднем карбоне некоторые группы видов и рода, появившиеся еще в нижнем карбоне, но не имевшие большого значения в составе нижнекаменноугольной фауны. Такова группа нижнекаменноугольного вида *Caninia juddi* Thom., рода *Fischerina*, *Corwenia* и особенно род *Bothrophyllum*, являющийся едва ли не самым распространенным родом среди среднекаменноугольных кораллов СССР.

Для среднего карбона Урала характерно также обилие видов рода *Caninia*, соперничающего по распространенности с родом *Bothrophyllum*. Наконец, новыми формами, развивающимися в среднем карбоне, являются *Multithecopora*, *Timania*, *Pseudotimania*, *Lithostrotionella*, *Cystophora* (на Урале отсутствующая), *Lytvophyllum*, *Koninckophyllum*, *Lophophyllidium*.

Несмотря на такие крупные различия между ниже- и среднекаменноугольными фаунами кораллов в то же время генетическая связь их друг с другом вполне ясна и среднекаменноугольная фауна представляет собою лишь дальнейший этап в развитии коралловой фауны нижнего карбона. Тесная родственная связь между указанными фаунами сказывается не только в наличии общих родов, но и в том, что появившиеся в среднем карбоне новые формы имеют своих предков в нижнекаменноугольных видах и родах.

Б. Изменения и развитие среднекаменноугольной коралловой фауны

Посмотрим теперь несколько более детально фауну кораллов среднего карбона с точки зрения ее 1) изменения во времени в пределах среднего карбона и 1) изменения ее в пространстве в пределах западного склона Урала. Некоторые положения, которые могут быть установлены в результате такого рассмотрения помогут нам уяснить стратиграфическое значение кораллов.

Остановимся несколько подробнее на фауне двух районов, а именно Кизеловско-Чусовского и Башкирского, ибо из этих районов описано подавляющее большинство кораллов среднего карбона. В коралловых фаунах обоих районов имеется по несколько представителей родов *Chaetetes*, *Caninia*, *Bothrophyllum*, *Camporphyllum*, *Koninckophyllum*; общими же родами, но представленными единичными представителями являются: *Pseudotimania*, *Lophophyllidium*, *Lithostrotion*, *Lithostrotionella*, *Lytophyllum*, *Corwenia* (Род *Lytophyllum* установлен Т. А. Добролюбовой для кораллов подобных *Thysanophyllum*, но обладающих столбиком).

Только в Кизеловско-Чусовском встречен род *Hapsiphyllum*, только в Башкирском рода — *Multithecopora*, *Cladochonus*, *Zaphrentis*, *Lophophyllum*, *Arachnolasma*, *Fischerina*, *Orionastraea*, *Dibunophyllum* (?).

Получается, что по родовому составу фауна Башкирии значительно богаче. Правда, надо при этом учесть, что перечисленные рода представлены в большинстве одним видом и немногими или даже единичными экземплярами и появление или отсутствие их в списке может в значительной степени зависеть от случайностей сбора.

Еще более крупные различия наблюдаются в видовом составе. Так, в башкирской фауне совершенно не обнаружена своеобразная группа мелких каниний (группа *Caninia irinae* Gorsky), широко распространенная в низах среднего карбона Кизеловско-Чусовского района. Также отсутствует группа *Caninia remotetabulata* Gorsky, свойственная Кизеловско-Чусовскому району, но зато в большом количестве экземпляров и несколькими видами представлена группа *Caninia nalivkini* Gorsky, отсутствующая в Кизеловско-Чусовском районе. Общим видом рода *Caninia*, богато представленного в той и другой группе, является единственный вид *Caninia mutafi* Gorsky.

Вторым существенным отличием является незначительное количество представителей рода *Bothrophyllum* в башкирской фауне, тогда как в Кизеловско-Чусовском районе они встречаются во множестве и по видовому составу гораздо разнообразнее.

Третьим отличием служит распространение в башкирской фауне неопisanого подрода, не встреченного в Кизеловско-Чусовском районе, а также весьма частое распространение в башкирской фауне *Lytophyllum tchernovi* Soschk. var. nov. — редкого в Кизеловско-Чусовском районе.

Эти существенные различия в родовом и видовом составе фауны, кроме случайностей и несовершенства сбора, имеющих значение лишь для редких родов и видов, объясняется: 1) несинхроничностью той и другой фауны и 2) различием фациальных условий.

Несинхроничность фаун действительно имеет место. Наиболее наглядное влияние данного фактора можно наблюдать анализируя фауну нижней части среднего карбона Башкирии и Кизеловско-Чусовского района. Средний карбон Башкирии разделяется на три свиты C_2^a , C_2^b и C_2^c ; средний карбон Кизеловско-Чусовского района также на три свиты — C_2^1 , C_2^2 и C_2^3 . Эти свиты не синхроничны.

Самые низы башкирского среднего карбона отсутствуют в Кизеловско-Чусовском районе, а хорошо развитые и богатые кораллами башкирские слои (горизонт C_2^b) повидимому лишь частично имеют аналогов в нижней свите (C_2^1) среднего карбона Кизеловско-Чусовского района. Иными словами в башкирском разрезе среднего карбона имеется часть разреза более древняя, чем в разрезе Кизеловско-Чусовского района.

Повидимому, этим обстоятельством можно отчасти объяснить различие в составе фауны кораллов, а именно присутствие в башкирской фауне таких родов, как *Dibunophyllum* (единичный экземпляр), *Fischerina*, крупные отличия в видовом составе рода *Camporphyllum*, большее число находок *Lithostrotion*, словом черты архаичности в фауне, показывающие близость к нижнекаменноугольной фауне.

Однако, объяснение несинхроничностью не подходит, когда мы сравниваем фауны верхних частей разреза повидимому синхроничных по времени своего образования.

Правда, остатки кораллов могли быть собраны не из вполне одновременных горизонтов, но и в этом случае остаются непонятными такие отличия, как небольшое число представителей рода *Bothrophyllum* в башкирской фауне, очень крупные различия в видовом составе рода *Caninia* и различия в родовом составе.

Указанные различия в фауне кораллов по всей вероятности надо объяснить не взаимной несинхроничностью коралловых фаун, а различиями фациальных условий, сказавшимися на характере пород. Весь разрез среднего карбона Башкирии, имея в виду район сбора коралловой фауны, представлен исключительно карбонатными породами, в основном состоящими из чистых известняков, в то время как в Кизеловско-Чусовском районе значительная часть разреза ($\frac{1}{3} - \frac{1}{2}$) состоит из пород со значительной примесью терригенного материала или же целиком из него. Сюда относятся породы свиты C_2^2 , — мергели, глинистые сланцы, песчаники, глинистые сланцы и т.п.

Рассмотрим изменения коралловой фауны в пределах среднего карбона по районам Кизеловско-Чусовскому и Башкирскому.

В Кизеловско-Чусовском районе коралловая фауна нижнего горизонта (C_2^1) характеризуется наличием группы мелких каниний (группа *Caninia irinae* Gorsky), малочисленностью и редкостью представителей рода *Bothrophyllum*, значительным распространением рода *Campophyllum* и появлением нового рода и группы *Koninskophyllum rhiphaicum* Gorsky, отличающейся простотой строения центральной зоны.

В среднем горизонте (C_2^2) происходит значительное сокращение мелких каниний почти до полного исчезновения при соответственном увеличении распространения рода *Bothrophyllum*; продолжает развиваться группа *Koninskophyllum rhiphaicum* Gorsky и появляются немногочисленные колониальные кораллы, принадлежащие к родам *Lithostrotionella* и *Lytvophyllum*.

Для верхнего горизонта (C_2^3) характерно обилие представителей рода *Bothrophyllum*, часто переполняющих известняк и разнообразных в видовом отношении, присутствие крупных каниний, составляющих часть линии развития от нижнекаменноугольной *Caninia juddi* Thom. к группе *Caninia kokscharowi* Stuck., изобилующей в верхнекаменноугольных и нижнепермских известняках западного склона Урала.

Башкирский средний карбон также разделен на три горизонта. Нижний горизонт C_2^a — который может быть даже частично относится к намюрскому ярусу, беден остатками кораллов. Средний горизонт (C_2^b), или башкирские слои, обладает богатой коралловой фауной. В этом горизонте появляются из табулат рода *Multiithecopora* и *Cladochonus*, из ругоз появляется новый род (см. выше многочисленные виды рода *Campophyllum* (особенно характерен оригинальный *Campophyllum contortulum* Gorsky), нового подрода указанного на ст. 54, и разнообразные рода колониальных кораллов — *Fischerina*, *Lithostrotion*, *Orionastraea*, *Lithostrotionella*, *Lytvophyllum*, представленных однако, за исключением последнего род, небольшим количеством экземпляров. Верхняя свита (C_2^c) характеризуется появлением группы *Caninia nalivkini* Gorsky, небольшого количества экземпляров *Bothrophyllum*, рода *Kionophyllum*, расцветом нового подрода который был уже указан на ст. 54.

Б. Возможности сравнения коралловой фауны среднего карбона Урала с соответствующими фаунами других областей

Может возникнуть вопрос — если коралловая фауна среднего карбона Урала так сильно отличается друг от друга в районах, расположенных на Урале, то быть может различие между фаунами Урала и других областей настолько велико, что никакое

сравнение между ними невозможно. Иными словами, не является ли фауна Урала чисто местной и непригодной для каких-либо стратиграфических и палеогеографических построений выходящих за пределы западного склона Урала.

Для решения этого вопроса надо сравнить уральскую фауну с другими, при чем материалами для сравнения могут служить лишь Подмосковский и отчасти Донецкий бассейны и до некоторой степени Китай, ибо для других районов коралловая фауна среднего карбона почти совершенно не изучена.

Сравнивая уральскую фауну с подмосковной приходим к следующим положениям. Уральская фауна по родовому составу значительно богаче — 24 рода против 17.

Общими родами являются: *Chaetetes*, *Bothrophyllum*, *Campophyllum*, *Dibunophyllum*, *Lithostrotionella*. В подмосковной фауне характерно обилие колониальных кораллов и представителей рода *Bothrophyllum*, тогда как в уральской колониальные кораллы встречаются редко, за исключением *Lytrophyllum*, кстати совершенно отсутствующего в подмосковной фауне. Далее из подмосковного среднего карбона не приводится ни одного вида *Caninia*, тогда как на Урале виды этого рода многочисленны и разнообразны. Правда, здесь возможно, что это обстоятельство зависит от различного понимания объема рода *Caninia* у авторов, но во всяком случае общий облик фауны в массе сборов для той другой области различен.

Следует признать, что хотя уральские среднекаменноугольные кораллы хорошо характеризуют возраст отдельных горизонтов (как и подмосковные), то тем не менее и та и другая коралловая фауны являются своеобразными, имеющими сравнительно мало сходства между собой, хотя обе несомненно являются среднекаменноугольными.

В уральской фауне наблюдается явный отпечаток родства с уральской же нижнекаменноугольной фауной по линии родов *Chaetetes*, *Cladochonus*, *Amplexus*, *Hapsiphyllum*, *Zaphrentis*, *Caninia*, *Bothrophyllum*, *Campophyllum*, *Lophophyllum*, *Koninckophyllum*, *Lithostrotion*, *Dibunophyllum*.

Сравнивая уральскую фауну с донецкой, также можно констатировать сравнительно очень небольшое сходство, примерно такое же, как с подмосковной фауной, или даже еще меньше. Также как и сходство между коралловыми фаунами донецкой и подмосковной. Так в донецкой фауне, при всем ее разнообразии, встречены лишь 4 вида общих с подмосковным бассейном, в уральской фауне видов общих с подмосковной фауной 6). Кроме того и по общему составу донецкая фауна отличается от уральской большим количеством колониальных кораллов, разнообразием одиночных кораллов со столбиком, среди которых установлено много новых родов, небольшим количеством и малым разнообразием каниний.

С китайской фауной уральская имеет общих 5 видов. Интересно отметить, что в китайской фауне редки представители такого характерного для среднего карбона рода, как *Bothrophyllum*, но в то же время в китайской фауне, как и в уральской, присутствует группа своеобразных *Koninckophyllum* со слабо выраженным столбиком.

Краткое сравнение среднекаменноугольных фаун четырех областей (Урал, Подмосковский бассейн, Донецкий бассейн, Китай) показывает, что коралловая фауна каждой области отличается значительным разнообразием при малом количестве общих видов и что поэтому *сравнивать эти фауны между собою можно только в общем виде*.

Если же взять коралловую фауну какой-либо области и проанализировать ее по стратиграфическим горизонтам, то нетрудно убедиться, что фауна каждого из горизонтов (если она имеется в достаточном количестве) обладает характерными особенностями достаточно отчетливо выраженными. Это обстоятельство заставляет признать, что кораллы, (в случае их достаточного распространения) являются надежными показателями в стратиграфии, пригодными для фаунистической характеристики дробных

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стратиграфических подразделений, но в более или менее узких пределах одного геологического района, с одними и теми же фациальными условиями.

3. КОРАЛЛОВАЯ ФАУНА ИЗВЕСТНЯКОВ ВЕРХНЕГО КАРБОНА И НИЖНЕЙ ПЕРМИ

На западном склоне Северного и частично Среднего Урала, на Уфимском плато и на некоторой части западного склона южного Урала на среднекаменноугольных отложениях залегает мощная толща известняков, ранее относившаяся целиком к верхнему карбону. В настоящее время верхняя половина этой толщи, начиная с появления *Parafusulina lutugini* Schellw., относится к нижней перми.*

Обработанный материал по коралловой фауне известнякового верхнего карбона и нижней перми для громадного пространства западного склона Урала от правых притоков р. Печоры (Подчерем, Шугор и др.) и до широты Стерлитамака.

Сравнивая весь этот большой материал, прежде всего бросается в глаза единство фауны, сказывающееся не только в родовом составе, но и в очень большом количестве общих видов. Так, виды родов *Orionastraea*, *Cystophora*, *Tschussowskenia*, *Thysanophyllum*, *Wentzelella*, *Lonsdaleiastraea*, установленные Т. А. Добролюбовой, были встречены во всех фаунах.

Из сравнения данных по Кизеловскому району, Уфимскому плато и Стерлитамаку оказывается, что комплексы коралловой фауны, установленные впервые Т. А. Добролюбовой для Уфимского плато, очень упорно и отчетливо выдерживаются и в других районах распространения известняковой толщи верхнего карбона и нижней перми.

Напомним, что Т. А. Добролюбовой намечались следующие четыре горизонта:—

- 1) Самый нижний с обилием массивных полипняков *Thysanophyllum perpastum* Dobr. *T. cystosum* Dobr., *Campophyllum* cf. *amplexoides* Stuck. Мощность около 44 м.
- 2) Выше идут известняки с *Orionastraea campophylloides* Dobr. *Cystophora biseptata* Dobr. и всеми видами рода *Thysanophyllum*, за исключением типичных *T. perpastum* Dobr. Мощность 124–130 м.
- 3) Выше залегают известняки со всеми видами рода *Orionastraea*, причем *O. campophylloides* Dobr. и *Cystophora biseptata* Dobr. встречаются реже, чем в нижележащем горизонте. Мощность около 140 м.
- 4) Верхний горизонт характеризуется *Cystophora wischeriana* Stuck. и представителями рода *Protolonsdaleiastraea*.

К еще более высоким слоям Т. А. Добролюбова относит известняки с *Lonsdaleiastraea*.

Если указанную последовательность горизонтов попробовать сравнить с распределением фауны кораллов в Кизеловском районе, то нетрудно убедиться, что два нижних горизонта Т. А. Добролюбовой, из которых самый нижний по бедности фауны не имеет самостоятельного значения по составу фауны и по мощности отвечают горизонту C_3^2 Кизеловского района.† В самом деле, в горизонте C_3^2 Кизеловского района были встречены: *Caninia longisepta* Greck., *C. sp. nov.*, *C. verneuli* Stuck. var. nov., *Timania schmidtii* Stuck., *T. schmidtii* Stuck. var. nov., *Campophyllum schrenki* Stuck., а из колониальных кораллов — *Lithostrotionella* (?) sp. nov., *Tschussowskenia captiosa* Dobr., *Cystophora biseptata* Dobr., *Thysanophyllum perpastum* Dobr., *T. aseptatum* Dobr. var. nov., *T. cystosum* Dobr., *T. cystosum* var. *major* Dobr., *Carcinophyllum indigae* Stuck.

* Д. М. Раузер-Черноусовой граница перми принимается ниже под слоями *Pseudofusulina anderssoni* Schellw. В. Е. Руженцов относит к перми еще более низкие горизонты с псевдошвагеринами.

† Горизонт C_3^1 из коралловой фауны имеет лишь *Cyathaxonia* sp. *Caninia kokscharowi* Stuck. var. *tschussowensis* Greck., *Lophophyllum* sp. поэтому не может считаться достаточно охарактеризованным по коралловой фауне. В разрезах Т. А. Добролюбовой нижележащие известняки также были бедны кораллами.

Третий горизонт Т. А. Добролюбовой соответствует нижней части горизонта P_1^i . Эта часть разреза верхнего палеозоя Кизеловского района наиболее богата кораллами и состав коралловой фауны вполне отвечает признакам, указанным Т. А. Добролюбовой для ее третьего горизонта.

Список кораллов для нижней части горизонта P_1^i в Кизеловском районе следующий: *Sinophyllum* sp. nov., *S. sp.*, *Laccophyllum* sp. nov., *Caninia* cf. *kokscharowi* Stuck., *C. kokscharowi* Stuck. var. nov., *C. lonsdalei* Keys., *C. sp. nov.*, *C. verneuili* Stuck., *C. mylensis* Stuck., *C. sp.*, *Timania schmidtii* Stuck., *T. schmidtii* Stuck. var. nov., *Diphystrotion* spp. nov., *Lithostrotion* (?) sp., *Orionastraea campophylloides* Dobr., *O. stuckenbergi* (Gerass.), *O. solida* Stuck., *O. solida* Stuck. var. nov., *O. brevisseptata* Dobr., *O. brevisseptata* Dobr. var. nov., *Lithostrotionella* sp. nov., *L. (?)* sp. nov., *Tschussowskenia captiosa* Dobr., *Cystophora biseptata* Dobr. var. nov., *C. (?)* sp. nov., *C. monoseptata* Dobr., *C. monoseptata* var. 2 Dobr., *C. cf. monoseptata* var. 3 Dobr., *C. monoseptata* var. 4 Dobr., *C. monoseptata* Dobr. var. nov., *C. wischeriana* (Stuck.), *C. wischeriana* (Stuck.) var. nov., *C. sp. nov.*, *Thysanophyllum aseptatum* Dobr., *T. aseptatum* Dobr. var. nov., *T. cystosum* Dobr., *T. cystosum* var. major Dobr., *Protowentzelella* sp. nov., *Wentzelella* spp. nov., *Lonsdaleiastraea (?) complexa* Dobr.

Повидимому четвертый горизонт, выделенный Т. А. Добролюбовой также попадает в пределы горизонта P_1^i Кизеловского района, судя по нахождению в данном горизонте *Cystophora wischeriana* (Stuck.).

Таким образом, из приведенного краткого сравнения фауны, можно видеть однотипность коралловой фауны верхнепалеозойской известняковой толщи Уфимского плато и Кизеловского района, причем сохраняется не только единый тип фауны, но и возрастная последовательность комплексов остается одинаковой.

Можно, следовательно, констатировать, что на громадном протяжении западного склона Урала, где имеют распространение известняки верхнего карбона и нижней перми распространена однотипная фауна кораллов, среди которой намечается два хорошо выраженных возрастных комплекса.

Если сравнить уральскую фауну верхнего карбона и нижней перми с соответствующими фаунами других районов СССР или зарубежных стран, то, как и для среднекаменноугольной фауны, окажется очень мало сходства.

Условия для сравнения с Подмосковным бассейном неблагоприятны, ибо в нем мы имеем коралловые фауны в низах верхнего карбона, в то время, как на Урале коралловая фауна происходит из верхней части верхнего карбона и нижней перми.

В Донецком бассейне по В. Д. Фомичеву (10) коралловая фауна происходит также из сравнительно низких горизонтов верхнего карбона при этом одиночные кораллы все описаны как новые виды, а из колониальных форм указываются лишь *Polythecalis* и *Lonsdaleiastraea*, при чем из заведомо верхнего карбона (свита 0).

Самарская Лука также не подходит для сравнения, ибо горизонты Самарской Луки с кораллами более древние, чем коралловые горизонты Урала и действительно общими видами являются лишь *Caninia lonsdalei* Keys. и *C. verneuili* Stuck.

Из соответствующих фаун зарубежных стран некоторые черты сходства в родовом составе можно наметить с пермскими фаунами Китая, но и общий тип фауны и видовой состав Уральской фауны и Китайской имеют мало общего, что повидимому объясняется более молодым возрастом китайской фауны и принадлежностью ее к другой зоогеографической провинции.

Коралловый комплекс горизонта C_3^2 соответствует примерно зоне с псевдошвагеринами. Следующий коралловый комплекс нижнепермский отвечает низам зоны с *Parafusulina lutugini* Schellw. (м. б. захватывая и самые верхние зоны с *Pseudofusulina anderssoni* Schellw.).

По брахиоподам примерно намечаются такие же соотношения. Слои с коралловым комплексом горизонта C_3^2 отвечают некоторой части разреза с так называемым уральским комплексом брахиоподовой фауны, и именно с нижним подкомплексом, харак-

теризующимся богатой и разнообразной брахиоподовой фауной: *Productus genuinus* Krot., *P. kutorgae* Krot., *P. transversalis* Tschern., *P. pseudomedusa* Tschern., *P. jakowlewi* Tschern., etc., *Spirifer lyra* Kut., *S. holzapfeli* Tschern., *Pseudomartinia*, *Martiniopsis*, *Wellerella*, *Pugnax*, etc.

Слои с коралловым комплексом горизонта P_1^i отвечает нижней части слоев с артинским комплексом брахиоподовой фауны с *Spiriferella saranae* Vern., *Productus stuckenbergi* Krot., *P. pseudoaculeatus* Krot., *P. orientalis* Fredericks, *P. ufensis* Fredericks, *P. gruenewaldti* Krot., *P. uralensis* Lich. (= *P. uralicus* Tschern.), etc.

Мощная толща известняков, отложение которой продолжалось в течение верхнекаменноугольной и частью нижнепермской эпох, представляет собой осадки одного и того же бассейна с сравнительно мало изменявшимися условиями обитания фауны при том изменявшимися в определенных рамках и направлениях.

По всей вероятности этими обстоятельствами объясняется и единство фаун, встречающихся в этой толще.

И лишь при резком изменении физико-географических условий и смене известняковых осадков песчано-глинистыми происходит более резкое изменение в коралловой фауне.

4. КОРАЛЛОВАЯ ФАУНА ПЕСЧАНО-ГЛИНИСТЫХ ФАЦИИ ВЕРХНЕГО КАРБОНА И НИЖНЕЙ ПЕРМИ

Этот раздел посвящен своеобразной фауне кораллов, встречаемых среди песчано-глинистых толщ, ранее относившихся к артинскому ерусу. В последние годы установлено, что песчано-глинистые осадки «артинского» типа распространены не только в нижней перми, но и в верхнем карбоне и даже в верхней части среднего карбона. В настоящее время еще нет полного и ясного представления об истинном возрасте «артинских» песчано-глинистых отложений в различных пунктах Западного склона Урала и стратиграфия этих толщ еще находится в периоде становления, но тем не менее можно отметить, что для южной части Северного Урала и для северной части среднего примерно от широты р. Колвы и до широты г. Чусового песчано-глинистые осадки являются более молодыми, чем нижнепермские известняки и в действительности имеют пермский возраст.

Южнее вдоль Уфимского амфитеатра имеет место постепенное замещение известняковых фаций нижней перми, верхнего карбона и верхов среднего карбона песчано-глинистыми терригенными фациями.

Еще южнее, к югу от Уфимского плато и примерно до широтного течения р. Белой опять появляются известняковые фации верхнего карбона и нижней перми, а к югу от р. Белой разрез нижней перми, верхнего, среднего и части нижнего карбона представлен песчано-глинистыми породами с прослоями известняков.

Коралловая фауна в песчано-глинистых толщах характеризуется преобладанием мелких одиночных кораллов, часто неправильной формы, с чрезмерным развитием некоторых признаков, крайне изменчивых с нерезкими видовыми признаками.

Часты представители родов: *Tachylasma*, *Stereolasma*, *Lytvolasma*, *Lopholasma* и др. из сем. Streptelasmidae, а также родов *Amplexus* (*Amplexocarinia*), *Cyathaxonia* (*Cyathocarinia*), *Plerophyllum*, etc.

Е. Д. Сошкина намечает присутствие двух комплексов коралловой фауны в песчано-глинистых толщах: один более древний, в котором преобладают представители сем. Streptelasmidae и другой, более молодой с преобладанием Plerophyllidae.

Сейчас еще нет данных, для увязки фаун песчано-глинистых и известковых фаций друг с другом, но в качестве примера можно привести факт, указывавшийся Е. Д. Сошкиной, что в Северном Урале в одном разрезе нижней перми слои с *Wentzelella* лежат выше слоев содержащих древний комплекс коралловой фауны песчано-глинистых фаций.

5. ВЫВОДЫ

1) В верхнем палеозое Урала намечается семь, в среднем карбоне — 3, в известняковых фациях верхнего карбона и нижней перми — 2 и в песчано-глинистых фациях — 2 комплексов коралловой фауны достаточно отчетливо отличающихся друг от друга.

Во многих разрезах, особенно в верхнем карбоне и нижней перми они встречаются во множестве, отличаются хорошей сохранностью и при небольших размерах кораллитов в колониях, дают возможность точного определения сравнительно небольших частей колоний.

2) Остатки кораллов не распределены равномерно по всему разрезу и по коралловой фауне сейчас можно охарактеризовать не весь разрез непрерывно, а лишь его отдельные отрезки, в которых сосредоточена большая часть остатков кораллов и таким образом наметить комплексы коралловой фауны.

3) Коралловая фауна верхнего палеозоя Урала, по крайней мере фауна известняковых фаций, представляет собою, начиная с верхов нижнего карбона, фауну, развивавшуюся в основном на месте, с очень слабым притоком чуждых форм. Основные особенности верхнепалеозойской коралловой фауны Урала были заложены еще в верхневизейское время и в основном данная фауна является фауной местной, значительно отличающейся от сходных по возрасту фаун других областей СССР и зарубежных стран.

Основными линиями развития коралловой фауны Урала и вместе с тем наиболее характерными особенностями ее в целом являются следующие. Обилие и разнообразие представителей рода *Caninia* и в большей своей части представляющих дальнейшее развитие группы *Caninia juddi* Thom., распространенной в верхах нижнего карбона Урала. Эта особенность весьма резко выражена в Уральской верхнепалеозойской фауне по сравнению например с фауной донецкой и особенно подмосковной.

Второй отличительной особенностью верхнепалеозойской коралловой фауны Урала является обилие в верхнекаменноугольных и нижнепермских известняковых отложениях колониальных кораллов, принадлежащих к родам *Diphyrotroton*, *Orionastraea*, *Cystophora*, *Thysanophyllum* и придающих фауне несколько архаичный облик. Более высокоорганизованные *Lonsdaleiastraea* как например *Protowentzelella*, *Wentzelella*, *Lonsdaleidae* составляют лишь небольшую часть фауны и появляются здесь позже, чем в других областях. До сих пор не найдено представителей таких родов как *Waagenophyllum*, *Polythecalis*.

Особенностью уральской фауны в известняковых толщах является также редкость представителей сем. *Streptelasmidae*, зато весьма богато представленная в фауне песчано-глинистых толщ.

4) Из сравнения коралловых фаун верхнего палеозоя Урала с близкими или аналогичными по возрасту фаунами других областей СССР и зарубежных стран, выяснилось, что в каждой области фауны обладают своеобразными особенностями, имеют мало общего между собою в видовом составе и даже в пределах областей выделяются отдельные районы, отличающиеся от других своеобразием фауны. Это объясняется тем, что кораллы, тесно связанные с условиями бассейна, в котором они обитают, больше зависят от этих условий, чем другие животные и поэтому физико-географические условия бассейна имеют для них определяющее значение в составе и типе фауны.

Отсюда вытекают весьма важные выводы методического характера: а) коралловая фауна при стратиграфической корреляции разрезов областей, обладающих несходными осадками имеет лишь сравнительно небольшое значение, позволяя делать какие либо выводы о возрасте, примерно, с точностью до яруса, при этом, чем сильнее разнятся осадки, тем степень точности выводов уменьшается; в) при сравнении коралловых фаун отдельных областей и районов необходимо очень тщательно учитывать характер осадков

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в каждом разрезе и только при этом можно делать те или иные выводы о соотношениях коралловых фаун различных разрезов. Только при указанных условиях можно будет избежать грубых ошибок при стратиграфической корреляции, пользуясь данными, полученными при изучении коралловых фаун. На примере сравнения коралловых фаун среднего карбона Урала, Подмосковного и Донецкого бассейнов мы видели насколько мало общего между фаунами разновозрастными, но обитавшими в бассейнах с различными физико-географическими условиями.

с) Зато в пределах области или района, характеризующегося единством фациальных условий, коралловая фауна обладает однотипностью и с большим постоянством выдерживается на всем пространстве с одинаковым типом осадков. В этих случаях наблюдается не только однотипность фауны в целом, но и более или менее одинаковый ход ее развития во времени в пределах всего бассейна.

При этих условиях возможности использования коралловой фауны для корреляций чрезвычайно велики и степень детальности и точности достигает масштаба горизонта или зоны (в тех случаях, когда коралловая фауна настолько богата и распространена в разрезе). Значение коралловой фауны для местных зональных подразделений весьма велико.

5) Сравнение коралловых фаун различных областей при своеобразии фаун, при подавляющем развитии местных эндемических форм, в каждой фауне, при незначительном количестве общих видов в основном ограничивается сравнением фауны в целом, чаще всего по родовому составу и в меньшей степени по группам видов. Это обстоятельство требует особой тщательности и точности в отнесении коралла к тому или иному роду, особенно в тех случаях, когда имеется несколько близких сходных родов, как например *Caninia*, *Caninophyllum*, *Bothrophyllum*, *Timania*, или другие группы сходных родов. Не обходимы в дальнейшем точно и тщательно разработанные родовые диагнозы, в тех же случаях, когда приходится пользоваться уже имеющейся литературой, необходим критический просмотр всех форм, могущих быть отнесенными к близкому роду. Только при этих условиях можно быть избавленными от ошибочного истолкования черт сходства или различия в коралловых фаунах.

6) При изучении коралловой фауны како-либо области или района характеризующихся единством фаций осадков и следовательно как уже было установлено, однотипностью фауны по составу и по направлению и скорости развития ее, необходимо придерживаться узкого понимания вида, избегая чрезмерных обобщений смазывающих отдельные мелкие этапы развития. При изучении какой-либо линии развития, необходимо отмечать таксономически все этапы достаточно определенно выраженные морфологически и хронологически.

Соблюдение этого условия дает с одной стороны возможность с надлежащей полнотой и убедительностью проследить развитие какой-либо формы или группы форм, а с другой стороны дает материал для фаунистической характеристики детального стратиграфического разреза данного района и тем самым вместе с другими группами для составления сводного биостратиграфического разреза.

При этом надо заранее отдать себе отчет, что применение узкого понимания вида еще более ограничивает возможности сравнения фаун различных областей или районов с иным типом разреза, и что стратиграфия, основанная на фауне, изученной при узком понимании вида имеет местное значение (как и всякая детальная стратиграфия) и применима лишь полностью в пределах данного района.

7) Применение узкого понимания вида, особенно учитывая довольно распространенный среди кораллов гомеоморфизм, требует возможно более полного изучения онтогении каждого вида с помощью серий шлифов. Это даст возможность не только разобраться в морфологических особенностях и их развитии у данной формы, но и понять генетические

соотношения между родственными формами, хотя бы и не всегда близость между ними была морфологически на разных стадиях развития наглядна.

8) Как уже неоднократно отмечалось, кораллы весьма тесно связаны в своем развитии с условиями места обитания и крупные изменения этих условий в ту или иную сторону сказываются на кораллах самым быстрым и решительным образом. Однако мы не располагаем как ими-либо вполне определенными данными о значении и влиянии различных экологических факторов на жизнь и развитие кораллов и в этом направлении предстоит большая интересная и благодарная работа на специально выбранных объектах исследования, требующая для своего успешного выполнения тщательно обдуманной и разработанной методики. Данные, полученные при изучении влияния экологических факторов вместе с тем будут чрезвычайно важным и при изучении вопрос о быстроте изменчивости кораллов и решение этих обоих вопросов должно проходить в самой тесной связи.

THE ALGAL AND ARCHAEOCYATHIDAN FACIES OF THE PROTEROZOIC AND CAMBRIAN OF SIBERIA AND A ZONAL CORRELATION

By A. G. VOLOGDIN
U.S.S.R.

ABSTRACT

A special search for stromatoliths within the Sayany-Altai system in the south of Siberia showed their absence or great scarcity in the strata of the old formations.

Archaeocyathida and the conjugate algae accompanying them (*Epiphyton* flora), which appeared at the boundary of the Proterozoic and the Cambrian, are but to a very slight extent represented in the area of the platform, where they are hardly rock-forming. On the other hand, in the folded zone of the south of Siberia, from Sikhote-Alin in the east to Central and Southern Kazakhstan in the west, Archaeocyathida at some places formed great reef structures up to the end of the Middle Cambrian.

Tectonic movements at the close of the Middle Cambrian led to a reduction in size of the sea basins in the south of Siberia and to their becoming more shallow in the north (Siberian platform), where new groups of animals appeared.

A stratigraphic subdivision of the oldest deposits of the platform may be made according to the remains of calcareous algae, on the basis of their systematics worked out by the writer. On the other hand, within the folded zone the Proterozoic as yet has no reliable palaeontological characteristic, although the Archaeocyathida-*Epiphyton* horizons of the Lower and Middle Cambrian are correlated in a comparatively easy and reliable way.

FLORAL SUCCESSION IN THE ESTUARINE SERIES OF YORKSHIRE

By T. M. HARRIS
Great Britain

ABSTRACT

The "Estuarine Series" of the Yorkshire Oolites consists of a thick series of deltaic rocks divided into four by marine bands. The plants of the deltaic rocks have remained ill-zoned, partly because of the bad localization of many specimens and partly because nearly all the collecting was from a very few localities. The outcrop has been searched for new plant localities and 150 have now been found which yield determinable specimens (mostly microfossils). These represent all four stages of the Estuarines and are numerous enough to give an indication of the changing frequency. Most species prove to have long ranges; but an unexpected finding is that a good many are frequent in the first and last stages but absent from the two middle ones, while others characterize the two middle ones alone. Two localities yielded a series of *Lepidodendroid* megaspores, doubtless from fragments of derived Carboniferous coal.

THE flora of the Yorkshire Estuarine Series has been the "World Standard" Lower Oolite Flora for a century. Although the plant-bearing rocks are thick and divided into four by marine bands, the history of the flora within this series has been little investigated.

The divisions are as follows:—

Marine Callovian.

"Upper Estuarine"—up to 200 feet.

Marine "Scarborough" or "Grey" Limestone.

"Middle Estuarine"—up to 72 feet.

Marine "Millepore Bed" or "Whitwell Oolite."

Part of "Lower Estuarine"—up to 110 feet.

Marine Ellerbeck Bed.

Part of "Lower Estuarine"—up to 160 feet.

Marine "Dogger" (varied age).

Marine Upper Lias.

In studying the flora difficulties have been met, of which the chief have been:—

- (1) many of the plant species were composite and vaguely defined;
- (2) most of the specimens were badly localized;
- (3) most of the specimens were obtained from a very few localities.

In my own work I have tried to remedy all three difficulties: in particular I have collected extensively over as much of the outcrop as possible instead of working intensively at the best localities as others have done.

Most of my new localities have been exceedingly poor ones, yielding perhaps only, one or two determinable species; even so I have called them "localities" and have used them as evidence. I have searched about two-thirds of the outcrop so far and have found some 150 of these "localities" which represent all levels in the plant-bearing (Estuarine) series. This number is at least ten times as great as was previously available and is large enough to show general changes.

Nine-tenths of the new localities are merely coals or shales yielding spores and pieces of cuticle when macerated. In order to give some idea of the nature of the evidence I will explain what happens when a Yorkshire Jurassic coal is macerated. The results vary: I take a typical case.

1-2 kgms. of coal are soaked in strong nitric acid for a week, and then washed and soaked in dilute

caustic soda. A black slime is produced. This is extracted with water and resistant fossils are isolated with a series of wire meshes.

The commonest resistant fossils are small spores and pollen grains which I have not attempted to investigate. The next commonest, also not investigated, are small pieces of charcoal—there is some evidence that they were charred before deposition. Incidentally it is possible to display the anatomy of such charcoal.

Cuticles are often abundant, especially from the stems of *Equisetum columnare*, and I think that most of the coals consist largely of the rotted stems of this plant, preserved where they grew. There are a number of cuticles of gymnosperm leaves, sometimes a dozen determinable species, also perhaps a few determinable seed cuticles and usually some determinable Lycopod megaspores resembling those of *Selaginella*. Such spores may be moderately frequent, up to 100, say, per 500 gms. of coal; but usually there are only 1–10 per 500 gms. This is in very marked contrast with a Carboniferous coal, where they are many thousand times commoner and form an appreciable fraction of the coal.

I believe it useless to express the percentage frequencies of the different spore species in these Jurassic coals. I have proved that these change greatly as a single coal or shale bed is traced laterally. (I do not express any view against the use of such percentages for Carboniferous coals.) In my own work I merely record the presence of a species when I find it, whether locally common or rare. The localities are however numerous enough to give a special meaning to "frequency." Thus for the 31 plant-bearing localities of the Upper Estuarine at present known, *Ginkgo huttoni*, occurring in 15, may be said to be fairly frequent; while *Zamites gigas*, occurring in only three, is relatively infrequent. I have no doubt that more intensive collecting from these localities would disclose further occurrences of both these species and raise the figures, but I feel sure *G. huttoni* would still lead.

The vertical ranges recognized from this study are, broadly, as follows:—

(1) Very few species indeed characterize one division only, but nearly all have long ranges. The lowest division indeed has about three fairly widespread, characteristic species, but the other divisions have none that are widespread.

(2) A large number of species range through the lower three divisions and either miss the "Upper" Estuarine or are very rare, being doubtfully recorded for one locality. It seems as though the "Upper" Estuarine was unsuited to the preservation of any but a very limited facies of the flora.

(3) Remarkable changes in frequency do, however, occur; these must be regarded as facies changes rather than as zonal changes. There is a considerable group of species which are fairly frequent in the lower half of the "Lower" Estuarine, absent or relatively rare in the upper half of the "Lower" Estuarine and in the "Middle" Estuarine, and then relatively frequent again in the "Upper" Estuarine. The familiar *Zamites gigas* is an example, but there are others, such as some megaspores as yet unnamed, which are similar in range but more frequent. There is a complementary range, species frequent in the two middle divisions but rare or absent in the first and fourth. The causes of these facies changes will not be discussed here; it may be assumed that they result from some fluctuation in life conditions.

These rather slight facies changes of the flora contrast with the changes of the marine bands. According to published lists, the faunas of the five associated marine bands are almost wholly different from one another so that almost any shell ought to show which of these five marine bands it came from. I am not competent to discuss which parts of these faunal differences are zonal and which due to changes of facies, but in any case facies must play a big part for some of these bands themselves show two facies with largely different faunas. I would, however, point out that two of the three intercalated marine bands have never been accurately zoned, and the third in only one of its parts. There is a need for further work.

Finally, I suggest the following possible changes in the naming of the Yorkshire plant-bearing rocks for consideration.

In the first case it is clear that the series has four divisions, not the three which the names "Lower," "Middle" and "Upper" Estuarines imply. There is no reason why the Eller Beck Bed, which separates

the two lowest, should be singled out for special neglect (except the historical reason that it was the last recognized). The floras of the two lower divisions are considerably different and demand distinct names for the rocks of their origin. There is no English word meaning something between "lower" and "middle"; perhaps this is why these rather inappropriate names have persisted. To me it would seem natural to call the four divisions of the plant-bearing series, "first," "second," "third" and "fourth."

The second suggestion concerns the name "Estuarine." Several writers have pointed out that the Yorkshire Estuarines are not estuarine at all but entirely of *deltaic* origin, and everything I have seen confirms this. On the other hand, the marine bands are clearly estuarine at their onset and sometimes at their end, too. Would it cause too grievous confusion to name the whole plant-bearing series the "Deltaic Series"? I would propose to divide it into the "First Deltaic," comprising the lower half of the "Lower Estuarine," the "Second Deltaic" for the upper half of the "Lower Estuarine," the "Third Deltaic" for the "Middle Estuarine," and the "Fourth Deltaic" for the "Upper Estuarine." I put forward these suggestions tentatively as a visitor to the field of Geology, and knowing little of Geologists' customs.

DISCUSSION

B. LUNDBLAD pointed out the favourable conditions for doing similar microbotanical work on the material of cores from bores drilled in the coal mining district of N.W. Scania, southernmost Sweden. She asked if the author had done or intended to do work on cores in connection with the studies of the floral succession of the Estuarine Series of Yorkshire.

P. C. SYLVESTER-BRADLEY contended that to change the well-established name "Estuarine Series" to "Deltaic Series" on the ground of inapplicability seemed unnecessary. Many other stratigraphical names would fall if given such a test. The Cornbrash by no means always gives a fertile soil; in some places the Corallian Beds are quite free of corals. On the other hand there is a clear need for new names to distinguish the upper and lower portions of the Lower Estuarine Series.

R. V. MELVILLE said that the Lower Oolitic (Bajocian and Bathonian) rocks of Britain contain a molluscan fauna which (apart from the ammonites) displays a general uniformity throughout and contains a large number of long-ranging species. As pointed out by the author, the apparent distinctiveness of the molluscan faunas in the marine beds of the Lower Oolites of Yorkshire may be due to collections having been made from a very few classic exposures; and it is permissible to expect that more widely extended collecting would tend to diminish the apparent differences between the marine faunas mentioned by increasing the relative importance of long-ranging forms. Apart from possible refinements of stratigraphical division resulting from detailed work on, e.g., the brachiopods and nerineid gastropods, the type of distribution-study carried out by T. M. Harris on the plants might be profitably applied also to the invertebrates. His work is to be welcomed as providing an example and a stimulating suggestion to workers on invertebrate fossils.

T. M. HARRIS, in reply, said that no bore-cores had been available; the localities are difficult stream sections, with a number of weathered old quarries and coal pits. He agreed that there is a need to distinguish the two parts of the Lower Estuarine by name. With regard to the name 'Estuarine,' he pointed out that this is always inappropriate in Yorkshire, while such terms as Cornbrash are at least sometimes appropriate.

FRESHWATER MOLLUSCAN FAUNAS AND THEIR IMPORTANCE IN STRATIGRAPHY

By T. C. YEN
U.S.A.

ABSTRACT

The abundant occurrence of freshwater molluscan shells in various strata should furnish valuable evidence as to age determination and as to the correlation of a single bed over wide areas. Sometimes these shells are the only fossils in a bed unconformably overlying another, and their accurate identification may then form the only available clue to the stratigraphic position of the enclosing deposit.

An acceptable application is primarily based first on accurate identification, and secondly on the common occurrence of the same fossil assemblage at any one stratigraphical level.

Although freshwater molluscan shells are comparatively simple in structure, their relatively few morphological characters can be used to differentiate systematic categories. The value of these features varies in different groups and even in forms of the same group. But a careful analysis of any single character, or of a combination of such characters, may often lead to accurate identification.

The assemblage can be obtained only through exhaustive collection. Sometimes the fossiliferous bed represents a certain facies in which a certain single form was accumulated and preserved. Such incompleteness in data will undoubtedly curtail satisfactory age determination or correlation over wide areas, and will also make an interpretation of habitat conditions almost impossible.

A number of continental beds in the Upper Jurassic, Cretaceous and Eocene of North America and Europe are discussed which are characterized by their freshwater molluscan species.

ON THE MOLLUSCAN FAUNAS OF THE MORRISON AND THE PURBECK FORMATIONS

By T. C. YEN
U.S.A.

ABSTRACT

Freshwater molluscan species occur abundantly in the Morrison beds of North America and the Purbeck beds of Europe, both of which are generally regarded as of Upper Jurassic age. A comparative study of these faunas is discussed.

Among the material examined there is no species common to the Morrison and the Purbeck formations, even of such widely distributed genera as *Viviparus*, *Valvata*, *Hydrobia*, *Planorbis*, *Lymnaea* and *Physa*. This is interesting as in places the assemblages of both formations show close similarity of ecological conditions. Moreover, the congeneric species of the two formations indicate near relationship, not only genetically, but also in terms of geological age.

Some of the Purbeck forms resemble morphologically those of the Bear River formation of Upper Cretaceous age in North America; others, such as species of *Pachychilus*, or *Goniobasis*-like forms, so far not known in beds earlier than the Purbeck and not occurring in the Morrison, have allied species repeatedly reported from Cretaceous and early Tertiary strata in both America and Europe.

Hence, it may be inferred (though not conclusively) that the Morrison formation in North America is older than the greater part of the Purbeck. It possibly represents a freshwater facies of the Portlandian.

DISCUSSION OF THE PRECEDING PAPERS BY T. C. YEN

T. M. HARRIS pointed out that the 'eggs' of Characeae (freshwater algae) agree generically though not specifically in the Morrison and Purbeck of Dorset. He asked if there were any species of shells in common between American and European lakes of to-day.

P. C. SYLVESTER-BRADLEY said that a group of invertebrate fossils well-known from Morrison and Purbeck Beds was the Ostracoda. Freshwater ostracods might be dispersed by wind over wide areas and thus had that advantage (as stratigraphical guides) over molluscs. These ostracods had been used for 98 years to subdivide the Purbeck, and more recent work had established definite evolutionary series in the genus *Cypridea*. It was remarkable that there was an identity of species in the Dorset, Wealden, Vale of Wardour and N.W. German areas, but only faunas of similar aspect in deposits of approximately the same age in the Swindon, Aylesbury, Swiss, French and American areas. The Tendaguru dinosaur beds of Tanganyika had not yet been searched for ostracoda. Such "general aspects" could not be considered sufficient to justify correlation. It would be interesting to know whether the author had studied the molluscan faunas of similar facies in the Middle Jurassic, such as the Upper Estuarine clay and *Viviparus* Marl of Oxfordshire, or the Great Estuarine Series of the Hebrides; and if so whether such faunas had a very different aspect from those of Upper Jurassic-Lower Cretaceous age.

GORDON Y. CRAIG asked if the Purbeck and the Morrison formations had been correlated on the basis of the relative abundance of the various genera—say 30 per cent of *Valvata* in the Morrison formation roughly equating with the percentage abundance of the corresponding *Valvata* genus in the Purbeck—or if they had been correlated simply on the basis of single corresponding genera.

T. NEVILLE GEORGE (on behalf of the author), in reply, said that T. C. Yen had made a study of Mid-Jurassic non-marine molluscs, particularly of the Western Isles, and had found that they constituted recognizably different assemblages from those of the Purbeck and Morrison Beds. The author had made no statistical comparisons of the Morrison and Purbeck faunas in terms of the relative proportions of species. It was doubtful if such comparisons would be of value. The Morrison beds were deposited under conditions variable both in time and place; and the whole Morrison fauna was of course not found at every fossiliferous exposure. Within the Morrison beds there were marked differences in proportions of species even between neighbouring localities. In reply to T. M. Harris he said that although there might be appreciable differences between the faunas of present-day freshwater lakes, the general aspect of those faunas remains Recent; and the differences between them would at least be of less degree than those between the faunas of successive geological periods.

LAS FACIES DE FAUNA Y FLORA DEL MESOZOICO SUPERIOR Y LA CORRELACION DE SUS ZONAS EN MÉXICO

Por F. K. G. MULLERRIED

México

ABSTRACT

Habiéndose investigado ya ampliamente la serie marina del Mesozoico superior (Oxfordiano superior al Senoniano) en México respecto a zonas estratigráficas, resta hacer en este estudio referencia a la facie continental con restos vegetales, moluscos de agua dulce y reptiles continentales.

En toda la serie del Mesozoico hay en México, por todas partes, uno que otro nivel con restos vegetales que frecuentemente se hallan juntos con invertebrados marinos o en capas de poco grosor que están intercaladas en estratos marinos, por lo que tales vegetales no pueden indicar facie continental. Pero ocurren en el norte de México, en la serie del Senoniano superior, estratos de gran potencia arcillo-arenoso-conglomeráticos, que incluyen restos vegetales, moluscos de agua dulce y reptiles continentales, indicadores del origen de tales estratos. Estos han sido encontrados en el noreste de Coahuila y región limítrofe de Nuevo León, entre Piedras Negras, Coah. y Lampazos, N.L.; en la Mesa de Guajardo al oeste de Saltillo, Coah.; en la región de Soledad al oeste de Coahuila; y en el norte de Sonora. En esta amplia región de la República existen extensiones de los referidos estratos continentales, de considerable potencia. Aun no se ha establecido su edad geológica exacta ni se han reconocido sus niveles estratigráficos, pero parecen corresponder al Senoniano superior.

Por lo tanto, no es posible establecer en la actualidad una perfecta correlación entre las zonas de la facie continental con las de la facie marina, en la serie del Senoniano superior, mientras que, respecto a los citados niveles de vegetales incluidos en serie marina, la edad ha sido establecida por los fósiles marinos acompañantes o por estar en la parte superior o inferior de determinado nivel de fósiles marinos.

Futuras investigaciones bien pueden establecer los niveles exactos de los fósiles variados, incluidos en estratos continentales del Senoniano superior en el norte de México.

LOS estratos del Mesozoico superior (Oxfordiano superior al Maestrichtiano) en México son marinos esencialmente, mientras que la facie continental es reducida tanto verticalmente como horizontalmente.

Los estratos marinos incluyen invertebrados, pocos peces y reptiles, y algas calcáreas, mientras que la facie continental está caracterizada por vegetales, reptiles, y moluscos. Existe facie transicionaria entre las dos, de lagunas salobres, etc., designada por C. Burckhardt como facie subcontinental.

Han sido estudiados los estratos marinos de preferencia, mientras que la facie continental es aún poco conocida lo mismo que la facie subcontinental. No obstante esto, parece indicado examinar en esto la facie continental para reconocer si es posible las zonas (niveles, horizontes) de fósiles característicos y llegar así a la correlación de estas con las de la facie marina, porque tal contribución paleontológico-estratigráfica puede tener importancia referente a los estratos supramesozoicos de México, puesto que el conocimiento de ellos es aún bastante reducido.

Respecto a la facie marina sobra examinarla, porque han sido establecidas ya bastantes zonas de fósiles de guía, primero por C. Burckhardt en 1930, y después, en 1943, 1944a y 1944b por R. W. Imlay, quien modificó algo la estratigrafía de las zonas de Burckhardt aceptando el resultado del estudio estratigráfico general de L. F. Spath (1933), mientras que el otro estudio de E. Dacqué (1934) aunque mencionado por Imlay, no ha sido tomado en cuenta por éste. En la imposibilidad de conseguir el estudio de Dacqué, acepto por el momento la modificación introducida por Imlay al sistema

estratigráfico de Burckhardt. No es necesario incluir publicaciones posteriores a 1944 en el sistema empleado por Imlay, porque aquellos no contienen modificación alguna de este.

Sí, es indispensable indicar una posible rectificación al sistema estratigráfico de México en dos regiones de períodos geológicos distintos, a saber: la del Senoniano superior en la región carbonífera del oriente de Coahuila y terrenos vecinos de Nuevo León, y la de las capas con *Barrettia* en el centro de Chiapas. Respecto a la primera región he demostrado, en un estudio actualmente en prensa, que E. Boese estableció la secuencia que posteriormente fué modificada considerablemente por C. Burckhardt, pero que todo tiende a dar crédito a E. Boese respecto a la secuencia establecida por él, mientras que la edad precisa de las zonas tiene que ser revisada lo que ya indicó Imlay. La secuencia de los estratos del Senoniano superior en la región carbonífera del oriente de Coahuila y terrenos vecinos de Nuevo León es como sigue:

Maestrichtiense:

Serie superior de capas marinas, siendo las terminales de origen salobre; arenisca y pizarra arenosa; ostras, restos vegetales, y dientes de tiburones; cinco niveles de amonites (*Sphenodiscus* y *Coahuilites*), y un nivel, basal, de *Exogyra costata* Say, etc. Grosor 150 a más de 350 metros.

Serie inferior de estratos continentales, también salobres y marinos; capas arcillo-arenosas; capas y bancos de carbón; restos vegetales, moluscos de aguas salobres, y bivalvos marinos, dientes de tiburones. Espesor 500 metros.

Campaniense:

Pizarra en alternación con capas de caliza, marinas; amonites, *Exogyra ponderosa* Roemer, y probablemente *Actaeonella* (*Trochactaeon*) *inconstans* Boese.

Referente a las capas con *Barrettia* hay que indicar que este paquiodonto fué considerado como de edad maestrichtiense, por H. Douvillé, C. T. Trechmann y L. M. R. Rutten, mientras que ya H. L. Hawkins en 1923-24 opinaba que el fósil de referencia era más antiguo. En 1936 he concebido la idea última y considero a la *Barrettia* como del Turoniano superior. Aún en 1937 H. J. MacGillavry defendió la idea de la edad maestrichtiense de la *Barrettia*, indicando además que deben existir fallas en el centro de Chiapas donde hice mis observaciones. He recorrido otras veces la misma región y declaro terminantemente que no pude observar fallas de alguna importancia, por lo que afirmo otra vez que el paquiodonto *Barrettia* es anterior al Maestrichtiano; pero hago la modificación de mi idea de 1936 en el sentido de que la *Barrettia* abarca el Turoniense superior y casi todo el Senoniense inferior.

Más no hay que agregar actualmente a lo conocido sobre la facie marina del Mesozoico superior.

Respecto a la facie continental, hay que indicar desde luego que no es conocida con seguridad en el Jurásico superior, Cretácico inferior y medio, en el Turoniense y Senoniense inferior. En estas formaciones geológicas sí existen algunas zonas con vegetales continentales; pero esto no indica que se trata de capas terrestres, puesto que son capas delgadas cuyos restos vegetales bien pueden haber sido traídos de tierra firme, porque de lo contrario deberíamos aceptar oscilaciones considerables del mar y de la tierra firme que son incomprensibles. Arriba en el Cretácico superior, en el Senoniano superior, sí existen series de sedimentos que incluyen vegetales terrestres no acompañados por fósiles marinos o salobres, en partes. Estos sedimentos están intercalados en serie potente de capas marinas y salobres, e indican oscilaciones o comienzo de ellas, comprensibles porque poco después en el límite del Cretácico y Terciario hubo una emersión mayor.

Las oscilaciones iniciales son reconocidas únicamente muy al norte de México, puesto que los sedimentos con fósiles continentales han sido encontrados: en el NE. de Coahuila y terrenos vecinos de Nuevo León; en la Mesa de Guajardo al oeste de Saltillo, Coah., en la región limítrofe de Coahuila y Chihuahua, al oeste de la Sierra de San Vicente; en la región del rancho La Soledad, Chih.; y en el noreste de Sonora (Burckhardt 1930, Imlay 1944).

En cada región se trata de sedimentos de gran potencia, que incluyen vegetales y reptiles continentales, o moluscos de agua dulce, pero carecen las capas de fósiles marinos, por lo que seguramente

son sedimentos continentales. Mas su edad geológica no está bien reconocida, como lo demuestra el análisis siguiente de cada una de las regiones citadas arriba.

La primera región, del noreste de Coahuila y terrenos vecinos de Nuevo León, ha sido bastante reconocida. En esta amplia región, entre Piedras Negras, Coah., y Lampazos, N. L., hay una potente serie del Senoniano superior que contiene sedimentos continentales y algunas capas marinas intercaladas, entre dos series marinas, la una del Campaniense y la otra del Maestrichtiense superior. La sección de referencia ha sido indicada ya en este estudio. Los sedimentos continentales incluyen capas y bancos de carbón, y restos vegetales (hojas, madera fósil), que pueden demostrar su origen continental. Pero existen en esta serie ciertas capas con moluscos de aguas salobres, y otras con bivalvos marinos y dientes de tiburones; y las salobres están intercaladas en la serie potente, demostrando las oscilaciones en la serie de referencia. Como las capas marinas y las salobres están intercaladas en la serie potente de 500 ms. de espesor, pero separadas de esta, se puede aceptar que ésta es de origen continental. Siendo la potencia de ella mayor que la de los estratos superpuestos del Maestrichtiano superior, y estando sobre la serie del Campaniense, se puede asignar a los sedimentos continentales que incluyen capas salobres y marinas, edad del Maestrichtiense inferior y medio, aunque es de admitir que no hay indicio exacto de esta edad por no haberse encontrado fósiles de guía que comprueben su edad. Esto mismo indica que no se conocen aún zonas (niveles) de fósiles de guía en esta serie.

La otra región, la Mesa de Guajardo al oeste de Saltillo, Coah., está caracterizada por arenisca y pizarra en alternación que incluyen reptiles fósiles y tienen enorme potencia de 2,000 ms. Esta serie está superpuesta a capas con *Exogyra ponderosa* y *E. costata*, del Santoniense, Campaniense y Maestrichtiense inferior, por lo que la primera es más reciente, es decir del Maestrichtiense medio y superior, aproximadamente. Los reptiles no han sido clasificados; pero probablemente son continentales. La edad aproximada de la serie, se paraleliza probablemente con los estratos continentales del noreste de Coahuila. Aún no se sabe si esta serie tiene intercaladas capas marinas, o si esté superpuesta por serie marina, como se sabe del noreste de Coahuila.

Menos aún se conoce respecto a la región limítrofe de Coahuila y Chihuahua, al oeste de la Sierra de San Vicente, donde según E. Boese han encontrado enormes troncos fósiles. No habiendo capas subyacentes o superpuestas, identificadas estratigráficamente, queda insegura la edad geológica de la madera fósil de referencia, aunque es de presumir que pueda muy bien ser contemporánea a la del noreste de Coahuila.

También es insegura la edad geológica de las capas con fósiles continentales que Haarmann ha encontrado cerca de Soledad, Chih., al sur de la Sierra Mojada. En la base de la serie hay marga de colores vivos, que está superpuesta por pizarra, pizarra arenosa, arenisca y conglomerado en alternación, conteniendo este último madera silicificada y dinosaurios, que según Burckhardt pueden ser contemporáneos a las capas con saurios de Big Bend, Texas, y como éstas últimas son de la edad de la serie con carbón de Texas y al noreste de Coahuila (véase Adkins, 1928), es posible que sean del Maestrichtiano inferior y medio. Es de decir expresamente que en la región de Soledad no existe prueba alguna acerca de la edad exacta de los fósiles de referencia.

Por último, en el noreste de Sonora han encontrado sedimentos con fósiles continentales e intercalación de capas con fósiles de aguas salobres y otros marinos. Por Cabullona y en otras localidades se observa según R. E. King la secuencia siguiente:

Grupo de Cabullona

810' (pies) toba riolítica

capas rojizas superiores

+ 2,100' pizarra arenosa de colores vivos, lentejones de arenisca, en la base arenisca clara con gasterópodos de agua dulce.

Pizarra de Packard, 1,800-2,500' pizarra, capitas de caliza apizarrada y de arenisca calcárea, capitas de ceniza volcánica y bentonita; fragmentos de vegetales y bivalvos marinos.

Arenisca de Camas, 1,220' arenisca, pizarra de colores vivos; bivalvos y gasterópodos de agua dulce, troncos silicificados.

PART X: FAUNAL AND FLORAL FACIES

Formación de Snake Ridge, + 2,000' conglomerado, arenisca, pizarra arenosa, pizarra carbonosa; fragmentos de madera, bivalvos y gasterópodos de agua dulce, y 100' debajo de la terminación superior de esta formación hay dinosaurios.

Grupo de Bisbee, marino, del Comanche según Stanton, 1905.

Según Imlay el Grupo de Cabullona es de sedimentos probablemente muy arriba en el Cretácico superior y de origen continental. En comparación con lo reconocido más al oriente es posible una edad aproximada del Maestrichtiense inferior y medio, como en el noreste de Coahuila, por el contenido de los estratos en el noreste de Sonora de vegetales, dinosaurios y moluscos de agua dulce.

De lo anterior se infiere que es probable que en el norte de México se encuentren extensiones de estratos continentales con fósiles terrestres y otros de agua dulce, reconocidos en varias regiones, cuyos sedimentos bien pueden ser de la misma edad geológica, aproximadamente, dado que incluyen los mismos tipos de fósiles, vegetales, reptiles, y moluscos.

Pero, no habiéndose fijado las zonas de fósiles y que ni siquiera han sido clasificados estos, es imposible actualmente hacer la correlación estratigráfica de la facie continental de referencia con la otra marina de México.

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LAS FACIES DE FAUNA Y FLORA DEL MESOZOICO EN EL NOROESTE DE LA AMÉRICA CENTRAL (DEL ISTMO DE TEHUANTEPEC A NICARAGUA)

Por F. K. G. MULLERRIED

México

ABSTRACT

Los estratos del Mesozoico (Triásico superior? al Senoniano) reconocidos en el noroeste de la América central (del Istmo de Tehuantepec a Nicaragua) son en su porción inferior de facie continental, con dos o más niveles de madera fósil y restos de hojas, no estudiados suficientemente para fijar los horizontes estratigráficos.

La porción superior del Mesozoico es de facie marina, pero únicamente han sido reconocidos pocos niveles estratigráficos del Cretácico. Cada uno de estos niveles queda basado generalmente en una sola especie encontrada, excepcionalmente en dos, lo que no siempre es suficiente para indicar el horizonte exacto. No se conoce intercalación de facie continental con fósiles en la serie marina del Cretácico. Únicamente se ha reconocido en el centro de Chiapas una capa con restos vegetales, un poco arriba de la serie con fósiles del Neocomiano, pero está encima de capas marinas y debajo de otras que algo más arriba son igualmente marinas, por lo que la capa citada debe ser de origen marino, aunque contenga restos vegetales continentales.

Al contrario a lo conocido en el norte de México, el Senoniano superior en el noroeste de la América central es marina, por lo menos en el centro de Chiapas donde están superpuestos concordantemente al Cretácico los estratos marinos del Paleoceno? y Eoceno, lo que comprueba la continuación de las condiciones marinas, en el Cretácico y posteriormente, en la región citada.

Parece interesante agregar respecto al problema estratigráfico de la *Barrettia*, que no existen fallas en la parte central de Chiapas, por lo que este paquiodonto es más antiguo de lo que se admite generalmente (MacGillavry 1937), y parece hallarse no solamente en el límite del Turoniano y Senoniano (Mullerried 1936) sino abarcar todo el Senoniano inferior, pero no se ha encontrado en las capas superpuestas, como consta por las exploraciones efectuadas en Chiapas, por Mullerried.

FACIES VARIATIONS IN THE ASMARI LIMESTONE *

By A. N. THOMAS

Iran

ABSTRACT

The Asmari Limestone of S.W. Iran exhibits a considerable variation of biofacies. The *Neoalveolina melo curdica* fauna is a biofacies laid down in a restricted sedimentary environment, but its consistent superposition on other Asmari Limestone faunas makes it of correlative value.

Below this zone there are basic facies-faunas of long range existing contemporaneously but in separate environments. In association with each basic fauna there are certain species of consistently limited vertical range which allow zonal distinctions and correlations to be made.

The *Austrotrillina-Archaias* fauna is the basic fauna of the Miliolid facies, and this facies interdigitates with a reef-facies having a *Rotalia viennoti* basic fauna. Species in a more uniform underlying Oligo-Eocene marl group are used as a control for correlation of the variable facies of the overlying Asmari Limestone.

I. INTRODUCTION

DESCRIPTIONS of the type succession of the Asmari Limestone and of the development at Gach Saran have been given by the author in a paper to Section E. of this Congress (Thomas, 1950b, p. 35). The present paper describes elements of the faunas and floras of the Asmari Limestone as developed in various sections spread out at intervals for 900 miles along the regional fold-trend.

Unpublished work by Mr. F. D. S. Richardson, of the Anglo-Iranian Oil Company, and by Dr. F. R. S. Henson, of the Iraq Petroleum Company, has greatly assisted the author's own studies. Dr. Henson kindly permitted the inclusion of references to new species in course of publication by him (published later in 1950). Without access to his careful work, much of what follows would not have been written. Mr. J. G. Child has placed at the author's disposal draft correlation charts of the Asmari Limestone, and the author has to thank him and Mr. P. T. Cox for numerous discussions and constant encouragement.

II. BIOFACIES OF THE ASMARI LIMESTONE

In the accompanying correlation chart the occurrences of the various biofacies of the Asmari Limestone and related formations are indicated by index letters against typical sections.

1. *The Neoalveolina melo curdica* fauna ("N").—This fauna is an excellent example of a restricted biofacies which in Iran and adjoining countries is also of correlative importance. The principal components of the fauna are *Neoalveolina melo* subsp. *curdica* Reichel, *Meandropsina iranica* Henson, *Dendritina rangi* d'Orbigny, Miliolidae, Anomalinidae, rare algae and bryozoa, and often a great abundance of fragmentary remains of echinoids, gastropods and lamellibranchs. By comparison with other parts of the Asmari Limestone the microfauna is a very restricted one in regard to numbers of species. The individuals of species known in other facies tend to be dwarfed. The frequent association of this fauna with nodules of anhydrite points to a highly saline environment in which only some organisms could survive. That a more variable contemporary fauna existed in the less saline parts of the sea is indicated by the intercalation of occasional shelly marly bands and of a marly band with *Miogyopsina* sp. and calcareous algae, and by the occurrence of the zone fossils in association with abundant *Heterostegina* sp. in marly limestones in Kuh-i-Pabda and neighbouring sections.

Although this is a facies-fauna typically restricted to one environment of deposition it is always

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found above the earlier faunas of the Asmari Limestone, and the earlier faunas are never found interstratified with it. The index fossil *N. melo curdica* is found in rocks of Vindobonian age in Turkey and Cyrenaica and closely similar varieties of the same species in the Vienna basin (Reichel, 1936-37, p. 110). The strata in Iran may be correlated with the Lower Vindobonian.

2. *The Miogypsina fauna* ("M").—Below the *N. melo curdica* beds there is typically a variable group of beds including sandy limestones, marls, marly limestones and penecontemporaneous conglomerates. These beds are associated with shelly limestones containing *Ostrea* cf. *latimarginata* Vredenburg, *Miogypsina* cf. *globulina* Michelotti, *Dendritina rangi* d'Orbigny and *Peneroplis evolutus* Henson.

The *Miogypsina* fauna is almost invariably found below the *N. melo curdica* fauna and is never found interstratified with it. A species of *Miogypsina* does occur in a narrow band in the overlying zone, but it is a smaller species than that found in the "M" fauna and is associated with a species of *Miogypsinoidea* with thick, pillared, lateral layers. *Miogypsina* sp. and *Miogypsinoidea complanata* are also found in lower beds of the Asmari Limestone but in association with a much more varied fauna, including *Austrotrillina* and *Archaias* and without *Ostrea* cf. *latimarginata*. The "M" fauna is thus a distinctive one, with a rather restricted assemblage, and although *Miogypsina* has a much longer range than is represented by these beds in S.W. Iran, the "M" beds are regarded as virtually contemporaneous. They are certainly homotaxial. They are referred to the Burdigalian.

3. *The Austrotrillina-Archaias fauna* ("T").—This fauna is found at all levels below the *Miogypsina* fauna down to the lowest Oligocene. It was probably a warm shallow-water fauna and consists of abundant Miliolidae and Peneroplidae with *Austrotrillina* cf. *howchini* (Schlumb.) and *Archaias* cf. *aduncus* (Fichtel & Moll). Associated with them are *Peneroplis thomasi* Henson, *P. evolutus* Henson and *Dendritina* sp., and also other species which are of zonal importance as described below under the "P" and "S" faunas. When the fauna occurs without its more restricted species it is impossible at present to say to which part of the sequence it belongs. Further work on *Austrotrillina* may enable species of that genus to be defined which could be used for zonal purposes. A "Massilinoid" trend has been noticed in certain forms, for example.

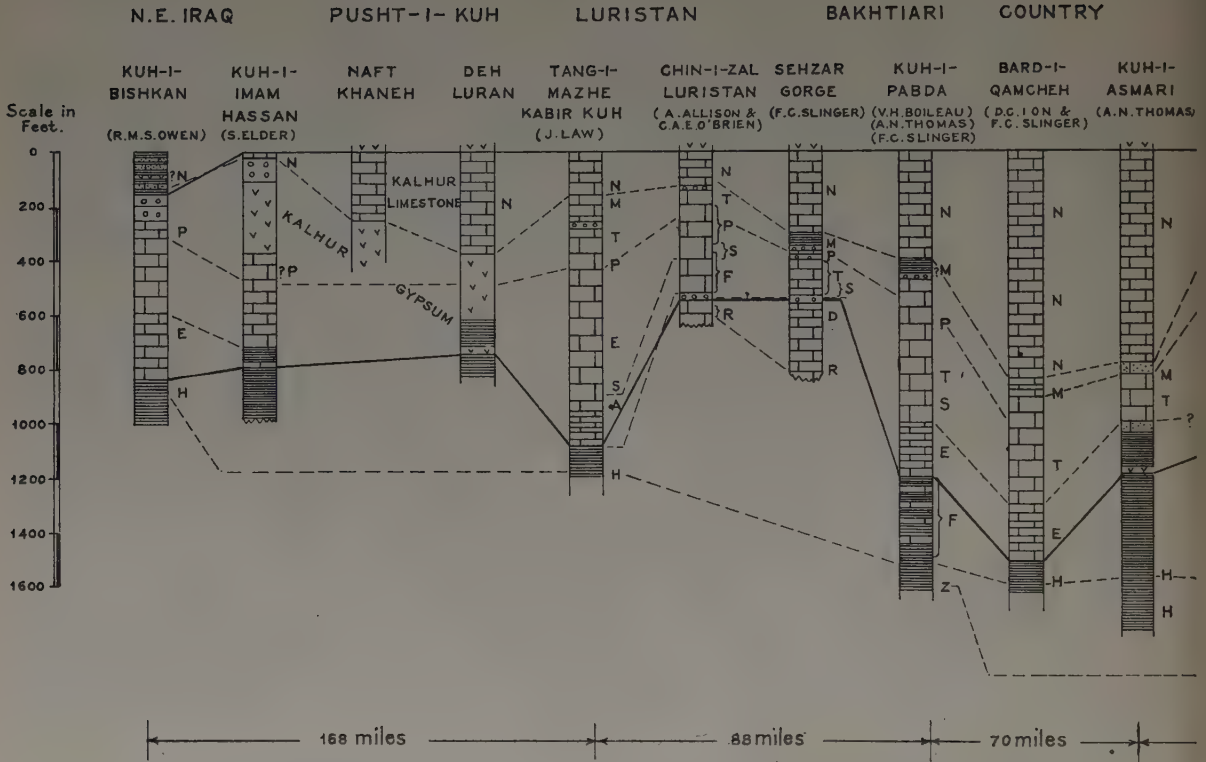
The "T" fauna in places occurs below the *Nummulites fichteli* fauna, as at Gach Saran and Kuh-i-Ginao; elsewhere it is interbedded with it, as at Kuh-i-Alhar. Most frequently, however, it occurs higher in the sequence, in fact immediately above Coral/Algal foraminiferal reef limestones which contain the "L" fauna described below. This appears to be a normal sequence of sedimentation in the basin of deposition.

4. *The Meandropsina anahensis fauna* ("P").—This fauna has been studied in detail by Dr. F. R. S. Henson, who finds it underlying the "Euphrates" Limestone (*N. melo curdica* fauna) of Iraq and separated from it by a stratigraphical break. The fauna is essentially the "T" fauna with the addition of *Meandropsina anahensis* Henson. In Iran it occurs at many localities as will be seen from Fig. I, and it is found in the higher part of the limestones underlying the *Miogypsina* fauna. It often underlies indications of a break in sedimentation, such as local conglomerates, rubbly limestones and erosion surfaces.

5. *The Praerhapydionina delicata fauna* ("S").—The earlier manifestations of the "T" fauna are accompanied by the distinctive forms *Praerhapydionina delicata* Henson and *Archaias operculiniformis* Henson. This specialized fauna is found overlapping or interbedded with the *N. fichteli* fauna at Gach Saran (in wells), at Chin-i-Zal (Luristan), and at Kuh-i-Alhar, southeast of Shiraz. In SW Iran the fauna most frequently occurs below the *N. fichteli* fauna, but it sometimes ranges to higher levels.

The "S" fauna is regarded as a shallow-water intercalation in a reef limestone sequence. It is restricted in geographical extent. For example it is found in the Gach Saran oilfield but is apparently absent from the reef limestone development at Tang-i-Gurguda 12 miles away. To the south of Gach Saran, at Sulabadar, the reef development is absent and the "S" fauna is found underlying limestones with a very restricted faunal assemblage which may be lagoonal. Again at Chin-i-Zal it is found

PART X: FAUNAL AND FLORAL FACIES



ASMARI LIMESTONE FAUNAS

- N. NEOALVEOLINA MELOGURDICA FAUNA
- M. MIOGYPSINA FAUNA
- T. AUSTRORILLINA-ARCHAIA FAUNA
- P. MEANDROPSINA ANAHENSIS FAUNA
- S. PRAERHAPYDIONINA DELICATA FAUNA
- L. ROTALIA VIENNOTI FAUNA
- Y. R.VIENNOTI - N.PYGMAEA FAUNA
- F. NUMMULITES FICHTELI FAUNA
- E. EULEPIDINA FAUNA
- A. BRYOZOAN - ALGAL REEF FACIES

OLIGO-EOCENE FAUNAS

- H. HAPLOPHRAGMIUM SLINGERI
- Z. ZEAUVIGERINA FAUNA
- D. DISCOCYCLINA FAUNA
- R. RHAPYDIONINA FAUNA

THOMAS: ASMARI LIMESTONE

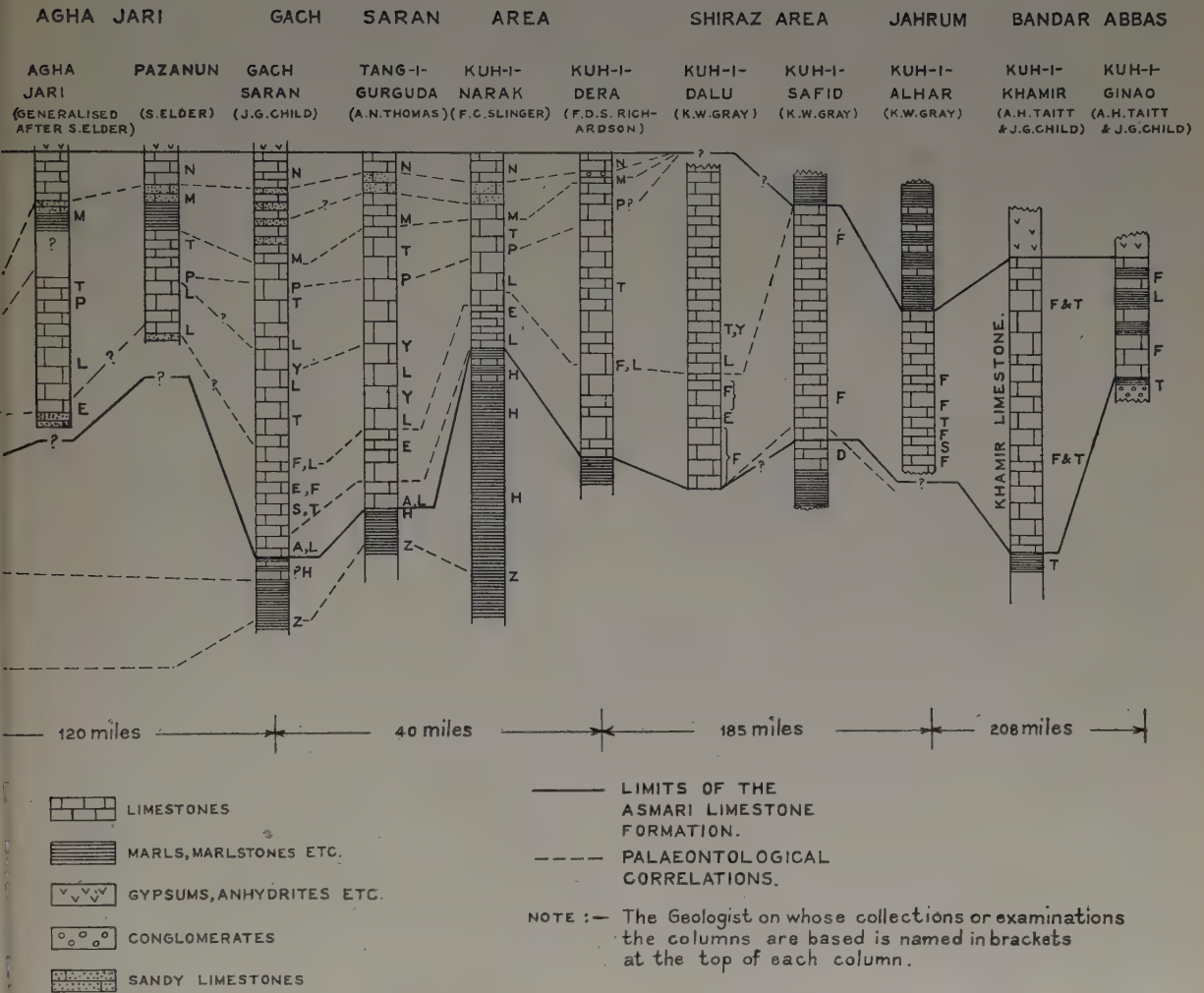


FIG. 1.—Correlation Chart of the Asmari Limestone of S.W. Iran, showing the Distribution of the various Faunas.

PART X: FAUNAL AND FLORAL FACIES

interbedded in several layers with *N. fichteli-intermedius* beds but is apparently absent from another section only a few miles away.

6. *The Rotalia viennoti fauna* ("L").—Just as the *Austrotrillina-Archaias* fauna forms the basic fauna of the Miliolid facies, so the *Rotalia viennoti* fauna forms the basic fauna of a reef facies. The typical constituents of the reef biofacies are corals and algae and large perforate foraminifera. *Rotalia viennoti* Greig is extremely abundant and certain bands may contain little else but swarms of this species. It is usually associated with other species of *Rotalia*, *Lepidocyclina* spp., *Heterostegina* spp., *Miogypsinoides complanata* (Schlumb.), numerous species of corallinaceae, bryozoa and encrusting foraminifera.

In the Asmari Limestone formation this fauna is always restricted to the lower levels. It has never been found interbedded with or in a stratigraphical position correlated with the *M. anahensis* fauna. The index species, *Rotalia viennoti*, is stated by Greig (1935) to be restricted to the Oligocene and lower levels, but later work suggests (*vide* Henson) that it does not occur below the Oligocene but does extend locally into the Lower Miocene.

There probably exists somewhere a similar facies-fauna corresponding in age with the overlying "P" fauna of the Miliolid facies, and it would be expected to contain survivors of the *R. viennoti* fauna, along with new forms such as the *Miogypsininae*.

7. *The R. viennoti-Neoalveolina cf. pygmaea fauna* ("Y").—In the higher levels of the *R. viennoti* fauna an association is found of *Neoalveolina cf. pygmaea* (Hanzawa) and large, fat *Heterostegina* sp. (cf. *H. assilinoidea* Blanckenhorn) with the basic fauna. The *N. cf. pygmaea* is not common, but it has served as a basis for local correlation in the Gach Saran area and is found at a similar level in the Shiraz area (Kuh-i-Dalu) and around Kazerun (Kuh-i-Dashtak).

8. *The Nummulites fichteli fauna* ("F").—This fauna is best developed in the Khamir Limestone of the Bandar Abbas-Jahrum-Shiraz areas. The limestone is sometimes made up almost entirely of the remains of *Nummulites intermedius* d'Archiac and *N. fichteli* Michelotti. Elsewhere in SW Iran it is found above and below the *Eulepidina* fauna. In the Gach Saran area and in Luristan *N. fichteli* is often a minor element of the *R. viennoti* fauna, but it is less common than *N. vascus* Joly & Leym. and other *Nummulites* in that fauna.

9. *The Eulepidina fauna* ("E").—Although *Eulepidina* occurs quite commonly in the reef limestones it is most abundant in stratified limestones from which corals are absent and in which algae are rare. Certain bands consist of little else but closely adpressed remains of *Eulepidina* with a few other lepidocyclines, *Cyclocypeus* and *Nummulites*. Usually the species can be referred to *Eulepidina dilatata* Michelotti, but specimens referable to *E. elephantina* Munier-Chalmas are found at Kuh-i-Khaviz.

The beds with *Eulepidina* can be mapped as a distinct, continuous member of the Asmari formation around some major anticlines, but until the faunas are worked out in greater detail it cannot be stated that the beds are everywhere contemporaneous. Probably they are not exactly so. Mr. F. D. S. Richardson has reviewed much unpublished evidence tending to show that the *Eulepidina* fauna preferred deeper water than the *N. fichteli* fauna. Whilst the *Eulepidina* fauna has often been regarded as younger than the *N. fichteli* fauna a reversal of this order of superposition occurs at Gach Saran and Kuh-i-Dalu.

10. *The Bryozoan-Algal Reef Facies* ("A").—The most distinctive member of this biofacies is a floral element. A new species of algae (cf. *Lithophyllum*) is easily recognizable wherever it occurs, usually in association with abundant *R. viennoti*, *Cyclocypeus*, *Lepidocyclina* (*Nephrolepidina*) spp., and bryozoa.

This biofacies is found at the very base of the Asmari Limestone in the Gach Saran area and again at Kabir Kuh 280 miles to the north-west. Mr. F. C. Slinger has recently found it in Kuh-i-Pabda. In each place it is found overlying the Oligo-Eocene marly beds with *Haplophragmium slingeri* Thomas and underlying beds with *Praerhapydionina delicata* Henson, above which come *Eulepidina* beds. The successions are homotaxial and probably contemporaneous. It is probable that elevation, either by sedimentation or earth movements, brought these parts of the sea floor into depths at which algae,

bryozoa and perforate foraminifera could flourish in great abundance and build up low flat reefs. Reef limestones higher in the sequence (above the *Eulepidina* beds) contain the same species of bryozoa and foraminifera, but the distinctive cf. *Lithophyllum* species is not found at the higher levels. It does occur, however, in the middle of the Khamir Limestone of Kuh-i-Khamir in beds with abundant *N. fichteli*. This helps to confirm the Oligocene age of the biofacies at the base of the Asmari Limestone of Gach Saran and Kabir Kuh.

11. *Oligo-Eocene Marls faunas* ("H" and "Z").—The Asmari Limestone is usually underlain by a marly facies of the Eocene and Lower Oligocene. The rocks are marls, marly limestones and calcareous shales with a microfauna of Globigerinidae, Buliminidae, Lagenidae and allied families. A high zone in this marly facies is characterized by the occurrence of *Haplophragmium slingeri* Thomas ("H" fauna), which has been found at several localities, as shown in Fig. I. Lower beds are characterized by *Zeauvigerina iranica* Thomas, a distinctive *Bolivina* sp., *Hantkenina* sp., *Rectogumbelina* sp. and *Planulina* sp. ("Z" fauna). The "H" and "Z" faunas have not been found interbedded or in the reverse order of superposition. There is a definite upper limit to the "H" fauna at Kuh-i-Asmari, although the same marly lithological facies persists to higher levels. This part of the marly facies is without *Haplophragmium slingeri* Thomas but contains *Zeauvigerina khuzistanica* Thomas. The "H" and "Z" faunas are therefore regarded as good zone faunas for the marly facies, and the upper limit of the "H" fauna can be used to control the correlation of the variable facies in the adjoining Asmari Limestone formation. Although it usually underlies the "A" biofacies and never overlies it, there is evidence to show that the "H" fauna is roughly equivalent in age to the "A" biofacies. Marly beds with the "H" fauna of Kuh-i-Narak can be traced laterally until they pass into Basal Asmari Limestone at Tang-i-Gurguda with the "A" biofacies. At Kuh-i-Pabda the "Z" fauna directly underlies a more calcareous facies with *N. fichteli*, suggesting that the "H" fauna is in the marly facies of the Lower Oligocene. The "Z" fauna itself overlies an underlying *Hantkenina* fauna and so is probably of Upper Eocene age.

12. *Eocene Limestone faunas* ("D" and "R").—In Luristan and in north-west Bakhtiari country the Asmari Limestone is found resting directly on "Eocene" limestones. The "D" fauna contains *Discocyclina* cf. *pratti* (Michelin) and *Nummulites* cf. *striatus* Bruguière, indicating an Upper Eocene age; it is separated from the Asmari Limestone by limestone conglomerates at the Sehzar Gorge. The "R" fauna underlies the "D" fauna at the Sehzar Gorge, but at Chin-i-Zal it is separated from the Asmari Limestone by a zone of crystallized limestones which may represent a considerable break in time.

The "R" fauna is a very distinctive one with *Rhapydionina*, *Rhipidionina* and new species of Peneroplidae and Miliolidae. It appears to be of Upper Lutetian or Upper Eocene age.

III. DISTRIBUTION OF THE BIOFACIES

The occurrence of the biofacies described above in SW Iran and contiguous territory in Iraq is illustrated in Fig. I. The general order of succession of biofacies and their distribution in the principal sedimentary environments is summarized in the accompanying table.

The "N" fauna and the "N" fauna with *Heterostegina* are found only in the upper parts of the limestone and the beds containing them are often underlain by indications of a break in sedimentation.

The "T" and "L" faunas are regarded as the basic faunas of the Miliolid and Reef facies respectively of the Asmari Limestone formation. In the former facies two distinctive faunas of stratigraphical value are recognized—the "P" and "S" faunas. The "P" fauna has been found in SW Iran only in rocks later than those containing the "S" fauna and the known reef facies-faunas. It is consequently regarded as a good stratigraphic index fauna in SW Iran. The "S" fauna is found in the lower levels of the Asmari Limestone formation interdigitating with the various faunas of the reef facies. In SW Iran the index species of the fauna, *Praerhapydionina delicata* Henson, appears to be restricted to the Oligocene and lower levels. It is never found overlapping the "P" fauna, although both faunas occur in the same sedimentary facies.

PART X: FAUNAL AND FLORAL FACIES

	Miliolid Facies	Reef and Reef Detritus	Marly Facies	Restricted Facies enclosed sea
MIDDLE MIOCENE			"N" Fauna with Heterostegina	"N" Fauna
LOWER MIOCENE			"M" Fauna	
AQUITANIAN AND OLIGOCENE	"P" Fauna			
	"T" Fauna	"Y" Fauna		
		"F" Fauna	"E" Fauna	
		"A" Biofacies	"H" Fauna	
UPPER EOCENE	"R" Fauna	"D" Fauna	"Z" Fauna	

THE DOUBLE LINES ENCLOSE THE BIOFACIES FOUND IN THE ASMARI LIMESTONE FORMATION

THOMAS: ASMARI LIMESTONE

In the reef facies the basic "L" fauna is present throughout, but local zoning is possible by discrimination of the "A" biofacies and the "F" and "Y" faunas. At Kuh-i-Khamir the most distinctive element of the "A" facies, the cf. *Lithophyllum* sp., has been found in beds with abundant *Nummulites intermedius-fichteli*. The latter fossil probably has a much longer range in time than is indicated by the occurrence of the "F" fauna in the above table. In the Shiraz, Jahrum and Bandar Abbas regions *Nummulites intermedius-fichteli* is extremely abundant in a non-reef facies and forms the major part of the local limestone. Before the true relationships of this limestone to the reef facies of the Asmari Limestone can be firmly established a study will have to be made of sections intermediate between Gach Saran and Shiraz.

The "E" fauna is roughly contemporaneous with the "F" and "S" faunas in the sections studied so far. It is found in thin-bedded limestones which appear to have been accumulated in deeper water offshore from the reef facies.

The "H" fauna is roughly contemporaneous with the "A" biofacies; broken fragments of the index species, *Haplophragmium slingeri* Thomas, are found sometimes in the reef facies associated with the "A" biofacies. It is more commonly found in its native environment in the marls or shales which are widespread geographically in the lower part of the Oligocene of SW Iran. The occurrence of the "H" fauna is used to control the correlation of the overlying "S," "T," "L," "F" and "E" faunas. The short stratigraphical range of *Haplophragmium slingeri* ("H" fauna) in strata at Kuh-i-Asmari which are in the marly facies from Eocene to Upper Oligocene suggests that it is a good time index fossil.

The "R," "D" and "Z" faunas are the Upper Eocene biofacies of the Miliolid, Reef and Marly facies respectively. They are usually separated from the overlying beds by indications of a break in sedimentation, either conglomerates and an erosion surface as at the Sehzar Gorge, or a condensed sequence of beds crowded with foraminifera, glauconite and collophanite which is generally the case in the marly facies.

Several of the biofacies described are regarded as approximately contemporaneous. Their order of occurrence in any one stratigraphical sequence depends upon the local geological history, and in other sections the sequence may be reversed or repeated several times. When the order is reversed and the same basic biofacies is repeated in the succession, it is found that certain species are of restricted vertical range and are of correlative value. It is the task of future palaeontological work to isolate more of these species of limited range and to define with greater precision the limitations of biofacies in relation to sedimentary environments. It is hoped that the results chronicled in this note will provide the framework for further and more detailed work.

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DISCUSSION

A. E. TRUEMAN asked whether the author had used the method of cellulose peels in the investigation of his material. If the limestone could be suitably treated in that way it seemed to him that it might provide a means both of getting a complete knowledge of the structure of an organism and of providing a basis for a three-dimensional reconstruction. Cellulose peels would also provide a complete record even of small specimens which were ground away. He suggested that this might supplement sections in giving an adequate basis for the description of new species.

L. R. WILSON asked if the author had seen any of the Silicoflagellates in his material, because in America they were now being found in abundance and were good horizon markers.

PART X: FAUNAL AND FLORAL FACIES

A. MORLEY DAVIES congratulated the author and his fellow workers on the great advance they had made in the palaeontology of Iran. He considered that the questions of the definition of the Aquitanian stage and the boundary between Oligocene and Miocene should be considered by a special commission of the Congress.

A. N. THOMAS, in reply to A. E. Trueman, said that the cellulose peel method had not been used in the examination of Iranian rocks. Critical sections of foraminifera were prepared by grinding rock fragments and varying the plane of grinding to obtain the correct orientation. The value of cellulose peels was realized but the time and personnel factors had not allowed of its application. In reply to L. R. Wilson he stated that no Silicoflagellates had been recognized or isolated in the Iranian rocks. With regard to A. Morley Davies's suggestion concerning the question of the position of the Aquitanian and the Oligo-Miocene boundary, attention should be drawn to R. Furon's report of the association of *Miogypsina irregularis* and *Eulepidina* at Qum in Central Iran and also the association of *Eulepidina* with *Pecten tietzi*. The Zagros range separated this biofacies from the Oligocene and Aquitanian of S.W. Iran and the stratigraphic relationship of the two biofacies would have to be elucidated by further work.

ON THE DISTRIBUTION AND LITHOLOGICAL IMPORTANCE OF NANNOCONUS LIMESTONES IN THE BATHYAL FACIES OF THE LOWER CRETACEOUS OF THE WESTERN MEDITERRANEAN

By G. COLOM

Spain

ABSTRACT

The extent and importance of the facies of fine-textured, sublithographic limestones containing *Nannoconus* is beginning to be well-known in the countries situated about the Western Mediterranean.

This paper presents a brief account of the range of this peculiar and formerly imperfectly known facies that is always found throughout the bathyal zones of Lower Cretaceous deposits.

The cement of these fine-grained limestone sediments is made up of an enormous accumulation of *Nannoconus* tests, nearly always associated with large quantities of radiolaria replaced by calcite, abundant fossil tintinnid loricas similar to existing species of tintinnids (oligotric planktonic infusoria), and two species of chlorophyllaceous algae belonging to the group of the Protococcaceae, *Globochaete alpina* Lombard and *Eothryx alpina* Lombard.

Up to the present *Nannoconus* sediments have been found in the Italian and Swiss Alps, in Provence (France), in the Balearic Islands (Ibiza and Majorca, but not Minorca), and in the Spanish Alps (Caravaca, province of Murcia).

THIS curious litho-palaeontological facies is now beginning to be well known throughout its classic locality of the Western Mediterranean. Its importance as a lithological element characteristic of Lower Cretaceous bathyal formations in the Mediterranean region grows more evident as our knowledge of its composition and geographical extent increases. Formations containing *Nannoconus* are now described in modern manuals of palaeontology, e.g., Glaessner (1945).

The writer has devoted a series of studies both lithological and micro-palaeontological in nature to this class of sediments since 1928; the latest, 1948a, is an extensive work in which the vicissitudes of pelagic sedimentation over the area of subsidence of the Mesozoic deposits of the Balearic Islands are followed in detail. An appreciable amount of data is now held on these once enigmatic formations, but it is not sufficiently detailed as yet for several countries. The purpose of the present paper is to give a summary of the data known.

Nannoconus was discovered by Professor J. de Lapparent, of the University of Strasbourg. In 1925 (de Lapparent, 1925a) he first described a new kind of fine-grained limestones formed in great part—or at times wholly—of minute, calcareous microfossils 25 to 30 μ long. These he named “embryons de *Lagena*,” as he supposed them to represent an early stage of development of a foraminifer belonging to the genus *Lagena*.

I was able to study this—at that time strange—facies with de Lapparent at Strasbourg in the following year. His material had been obtained from two different localities. Some came from the Gigondas massif in Provence and belonged to Berriasian strata from the environs of Suzette; the other rocks were from the Balearic Islands (Spain) and had been collected by Professor Paul Fallot from Neocomian strata.

On returning to Spain I began the study of the Mesozoic deep-sea formations of the Balearics and found these fine-grained, sublithographic limestones replete with de Lapparent’s “embryons de *Lagena*.” Two notes (Colom, 1928a, 1931) published in Spanish reviews gave further details of the range and lithological characters of the facies. In the second, especially, I was able to give an almost

complete description of the distribution of this type of sediments through the bathyal deposits of the Upper Tithonian and Lower Cretaceous in the largest of the Balearics, Majorca.

In view of these studies de Lapparent in 1931 again described his diminutive fossil, naming it *Lagena colomi*. These same micro-organisms had been found by other investigators, and Kamptner, also in 1931, described them under the name of *Nannoconus steinmanni* (Kamptner, 1931). Kamptner's slides came from Steinmann's studies of the deep-sea, sedimentary series of Northern Italy, especially from the fine, whitish, sublithographic limestones called "majolica" throughout the zone of Liguria. With the publication of these two notes, de Lapparent's *Lagena colomi* (his primitive "embryons de *Lagena*") and *Nannoconus steinmanni* Kamptner were shown to be identical. But more important than the clearing-up of the synonymy of the organism in question was the revelation of a wider distribution of the new lithological facies along the abyssal zones of the Mediterranean geosyncline during the Lower Cretaceous.

Subsequently, these microfossils were recorded from different zones of the Swiss Alps by Professor Cadisch in a work on the geology of that region (Cadisch, 1934), and again by G. Murgeanu, of the Geological Institute of Bucharest, from Lower Cretaceous levels also, in the valley of Prahova, near Comarnic. In the Rumanian deposits they were not abundant, as the deposits had been subjected, Murgeanu points out, to strong near-shore influences (Murgeanu, 1931).

Later, Professor de Lapparent demonstrated that the fine-grained sediments of the white, sublithographic limestones called "Biancone," from the region of Val Breggia, near Chiasso in Northern Italy, were, seen under the microscope, none other than fine lime-mud containing enormous quantities of *Nannoconus* shells associated with calcite moulds of Radiolaria and several different species of *Calpionella*. His note (de Lapparent, 1935) gave very interesting new information on their geographic and stratigraphic distribution.

There is now no doubt that *Lagena colomi* and *Nannoconus steinmanni* are the same thing and that these names are synonyms. It must be, and it has been, admitted that this fossil is not a true Lagenid and that, therefore, the generic name to prevail should be the one given it by Kamptner. The present complete synonymy might possibly be as follows:

Nannoconus colomi (de Lapparent), 1931

- 1925a "Embryons de *Lagena*" de Lapparent, p. 104, fig. 1.
- 1925b "Embryons de *Lagena*" de Lapparent, p. 351, Pl. X, fig. 1.
- 1928a "Embriones de *Lagena*" de Lapparent; Colom, p. 393, Pl. X, figs. 1-3.
- 1928b "Embriones de *Lagena*" de Lapparent; Colom, Pl. I, figs. 1,2.
- 1931 "Embriones de *Lagena*" de Lapparent; Colom, p. 529, Pls. V-VIII.
- 1931 "Embryons de *Lagena*" de Lapparent; Dervieux, p. 21.
- 1931 *Lagena colomi* de Lapparent; de Lapparent, p. 222.
- 1931 *Lagena colomi* de Lapparent; Murgeanu, p. 281.
- 1931 *Nannoconus steinmanni* Kamptner, p. 228 (with figures in the text).
- 1934b *Lagena colomi* de Lapparent; Colom, p. 5.
- 1935 *Lagena colomi* de Lapparent; Thalmann, p. 715.
- 1935 *Lagena colomi* de Lapparent; de Lapparent, p. 43.
- 1944a *Nannoconus colomi* (de Lapparent); Fallot, pp. 10, 12, 37, 38, 90.
- 1945 *Nannoconus colomi* (de Lapparent); Colom, p. 123.
- 1948a *Nannoconus colomi* (de Lapparent); Colom.
- 1948b *Nannoconus colomi* (de Lapparent); Colom, p. 252, fig. 7.

The taxonomic position of *Nannoconus* is still undefined. From the beginning some investigators have considered these fossils as true foraminifera because of the peculiar structure assumed by the calcite of the test walls. Others suppose that they might have belonged to certain very inferior groups of algae that produced calcareous tests sheltering chromatophores and moved by means of one or more

flagellae. Again, it is even believed that they are simply crystallizations of calcite in a strong lime medium.

The test of *Nannoconus* is calcareous, hialine, conoidal and somewhat flattened at the base. Its length varies between 25 and 30 μ . Its wall is composed of a series of calcite laminilles not always equal in size, disposed more or less at right angles to the axis of the test and arranged in a single layer. Between the laminilles there exist very fine canals communicating with the exterior and thus giving origin to the secondary perforations of the test. This recalls the wall-structure of several genera of the foraminifera; the latter, nevertheless, always reach a higher grade of complexity. The central cavity, in which the protoplasm would have lodged, is generally reduced to a simple, narrow canal. In some specimens its base is slightly more widened than in others (Colom, 1948b, p. 252, fig. 7). This cavity narrows progressively and at the mouth measures barely one μ in diameter.

In thin rock-slices the countless, diversely oriented and haphazardly sectioned shells present a false fibrous appearance. When sections are obtained exactly along the longitudinal axis of the shell, they are then seen quite clearly (Colom, 1948b, p. 252, fig. 7). In transverse sections, however, they resemble coccolith discs, and Steinmann took them for such when he came upon them in his studies of the deep-sea sedimentation of the Alps.

The constant symmetry of these shells—all alike in the hundreds of specimens that I have been able to study both in hard limestones and free and separate in marls from the lowest levels of the Majorcan Aptian—leads me to consider them micro-organisms and not simple crystallizations of calcite.

Although its wall-structure may in a way recall that of certain foraminifera, it does not seem possible at present to continue including *Nannoconus* in that group. Its minute size, the simplicity of its test, lacking a proloculum or initial chamber, and the fact that microspheric and megalospheric forms cannot be distinguished among the specimens, have led me to withdraw it from the foraminifera (Colom, 1945). I still consider it a doubtful form. Compared with other microscopic organisms, it reveals close affinities with de Lapparent's *Fibrosphaera* (Colom, 1945; de Lapparent, 1924), whose taxonomic position is also uncertain. *Fibrosphaera* is a calcareous body, spheroidal in shape as its name implies; its wall-structure is analogous in arrangement to that of *Nannoconus*. Its diameter is also some 30 μ . It was first described by de Lapparent in 1924 as occurring abundantly in fine-grained sediments of bathyal origin, both from present seas and from the Jurassic and Cretaceous.

From a palaeontological point of view, the chief problem *Nannoconus* presents is its taxonomic position. But interesting as its morphology and systematic relationships may be, an even more interesting point for the geologist is the intense part it has played as an element of prime importance in the formation of marly-limestone bathyal sediments in the Upper Tithonian and Lower Cretaceous of the Alpine-Mediterranean region. *Nannoconus* sediments represent a very peculiar lithological facies which may be described as follows.

The sediments—especially when the facies is very pure—appear in the form of compact, hard, marly-limestones, white or grayish-white in colour, and sublithographic in aspect because of their exceedingly fine matrix. The alternation of their beds with others of like nature but more clayey and so somewhat greenish, especially in Spanish deposits, is another wide-spread character. In the Balearic Islands and the regions of the Sierras Béticas, the majority of the deposits generally contain very richly fossiliferous strata with an exclusive fauna of ammonites indicating, at different localities, Valangian, Hauterivian and Barremian beds. Among these ammonites the smooth forms—*Phylloceras*, etc.—very characteristic of Mediterranean Tethyan bathyal deposits, predominate and give a typical faunistic whole of stenothermal beings. The analogies of these associations of Balearic ammonites with their contemporaries from other nearby localities, such as the Vocontian fosse in Provence (France) and the deep-water deposits of Algiers and Tunis, are well-known.

Seen under the microscope *Nannoconus* sediments resolve into a fine-grained lime-mud, comprising three basic elements: coccolith discs, *Nannoconus* and calcite granules. The coccolith discs are extremely abundant and are easily visible on the thinner edges of slides, as they give under crossed nicols a very characteristic helicoidal black cross. *Nannoconus* shells predominate in the sediments.

It is necessary to use very thin sections for their study; otherwise they may pass unnoticed. Because of their great abundance it is always easy to find, among the different shapes obtained by haphazard cutting, perfect longitudinal sections and transverse ones equally very characteristic. The third element, calcite in the form of tiny grains or, in some cases, in tiny rhombohedra, is always found scattered throughout the cement. Where the facies is very pure, however, calcite in grains or rhombohedra scarcely exists or is totally absent. At other times the calcite may predominate and give transitional sediments in which the fluctuation of the three elements may vary within certain limits. In spite of this, the preponderance of *Nannoconus* is always such as to warrant designating the sediments by this name.

Few mineral elements are present, for it is characteristic of the facies that, owing to its depth or to the pelagic nature of its deposits, the amount of detritic material that could reach them may be considered a minimum or nil. At the initiation or the continuation of a coastal regime with its consequent introduction of clastic elements, *Nannoconus* tends to disappear rapidly. The siliceous residue obtained from this limestone in the Balearic Islands and the Spanish Alpids gives, then, only a few quartz granules, rare muscovite straws, an occasional tourmaline or zircon crystal, and, in some deposits, very rare, minute grains of glauconite. The scarcity of this last would seem to indicate that they were not formed "in situ" but, rather, originated in a distant zone situated possibly nearer the coast. Other amorphous granules of calcium phosphate, probably fragments of bone, appear from time to time in the slides.

In many of the sediments there seems to exist a slight, siliceous impregnation, rapidly revealed when a rock-section is attacked by acid. Under crossed nicols this impregnation becomes, in some cases, quite clear.

The only organisms seen in the sediments are essentially pelagic ones and they belong to three different groups: Radiolaria (frequent and constant in almost all the beds), Tintinnids (infusoria of the Order of the Oligotricha), and chlorophyllaceous algae of the group of the Protococcaceae.

Radiolaria are extremely abundant, and more so at some levels than at others; this may be due to the better preservation of their skeletons at such levels by the calcium carbonate that replaces the original silica. In general, only simple moulds, filled with calcite crystals and with no traces of their peculiar structure remaining, are found, but in some cases the central capsule, long spines and other characteristic fragments are admirably preserved. In some few instances my slides show skeletons completely replaced by iron oxide, but otherwise they are all replaced by calcite in these Cretaceous formations. It is evident that a rich and constant plankton of Radiolaria was maintained during the course of numerous ages over the zone of subsidence of the Upper Jurassic and Lower Cretaceous seas of southern Spain and the Balearic Islands.

The second group of planktonic organisms frequent in these deposits is that of the Tintinnids, formerly known as the Calpionellae. Their taxonomic position was defined in 1934 (Colom, 1934a), the discovery of a number of quite varied species of *Calpionella* enabling me to attribute these once enigmatic forms to the large group of free-swimming, planktonic, oligotric infusorians that are still very abundant in existing seas. This identification was confirmed by Thalmann (1937b) and Deflandre (1936).

The first *Calpionella* described was *C. alpina* Lorenz (Lorenz, 1901). In 1932 Professor J. Cadisch, of Geneva, recorded two other species, *C. elliptica* Cadisch and *C. oblonga* Cadisch (Cadisch, 1932). Many more species of fossil Tintinnids are now known, some of them notable for their size and for their morphological similarities to living genera (Colom, 1948b).

Tintinnids occur in great masses in *Nannoconus* sediments. Their loricas, beautifully replaced by calcite, appear white against the dark gray matrix; their walls are thin and give perfect silhouettes resembling funnels, chalices, and other shapes, and sometimes show long, caudal appendages. Some beds are replete with them, while in others they are scarce or wholly lacking. In general in the Balearic Islands the same rhythm of frequency between Tintinnids and Radiolaria is observed as was noted by Andrusov & Koutek (1927; and Andrusov, 1931) in the Carpathians; that is to say, where the one

COLOM: NANNOCONUS LIMESTONES

abounds the other either disappears or is present in very small numbers. Up to the present it has not seemed possible to give a satisfactory interpretation of this alternation between the two organisms.

The abundance of Tintinnids in *Nannoconus* limestones in the Balearic Islands and the Sierras Beticas of Spain, as well as in some localities of the Rumanian Carpathians according to Murgeanu & Filipescu (1931, 1938), reveals the richness of that plankton throughout the pelagic and deep-sea zones of the Mediterranean geosyncline. Its different species range from the Tithonian, where they first appear, to the Barremian, but are especially abundant during the Berriasian-Valanginian and a great part of the Hauterivian, giving good index-fossils. It is impossible for me to enter here into a detailed study of their mode of preservation and stratigraphic importance, but the accompanying table shows the stratigraphic distribution of the principal species of Tintinnids in the Tithonian and Lower Cretaceous of the Balearics.

	Tithonian	Berriasian	Valanginian	Hauterivian	Barremian
<i>Calpionella alpina</i> Lor.	_____	_____			
<i>Calpionella elliptica</i> Cad.	_____	_____			
<i>Calpionella undelloides</i> Col.	_____	_____			
<i>Calpionella massutiniana</i> Col.	_____	_____	_____		
<i>Calpionellopsis thalmani</i> Col.			_____	_____	
<i>Calpionellopsis simplex</i> Col.			_____	_____	
<i>Calpionellites darderi</i> (Col.)		_____	_____	_____	
<i>Calpionellites neocomiensis</i> Col.		_____	_____	_____	
<i>Stenosemellopsis hispanica</i> (Col.) ...		_____	_____	_____	
<i>Favelloides balearica</i> Col.		_____	_____	_____	
<i>Favelloides pseudoserrata</i> Col.		_____	_____	_____	
<i>Tintinopsella carpathica</i> (M. & F.) ..		_____	_____	_____	
<i>Tintinopsella longa</i> (Col.)		_____	_____	_____	_____
<i>Tintinopsella cadischiana</i> Col.		_____	_____	_____	_____
<i>Tintinopsella batalleri</i> Col.		_____	_____	_____	
<i>Amphorellina lanceolata</i> Col.			_____	_____	
<i>Amphorellina acuta</i> Col.			_____	_____	
<i>Rhabdonelloides inesperatta</i> Col. ...			_____		

I think that there is no longer any possible doubt as to the true nature of the so-called "Calpionellae." They now figure as true fossil Tintinnids in such authoritative works as, for instance, the "Manuel de Paléontologie" of Professor L. Moret (1940). Therefore, I do not agree with J. Wanner when, in creating a new family, Codosinidae, for a group of protozoa whose systematic position is still doubtful [in a work published in 1940 (Wanner, 1940) but which did not come to my notice until recently], he includes among them the former genus *Calpionella*.

The third and last group of pelagic organisms was described by Professor Lombard, of Geneva, in 1937 and 1945a. These are two species of very simple, minute algae, whose preservation it would seem impossible to effect in any class of sediments whatever. They are, nevertheless, found admirably preserved in slides from the Tithonian and Neocomian of the Balearics. One—the more abundant—is a chlorophyllaceous protococcacean, *Globochaete alpina* Lombard, and the other, *Eothrix alpina* Lombard, belongs to the Ulothricaceae. Both species occur in great numbers in the Balearics, but never in so great an abundance as *Nannoconus*, Radiolaria and Tintinnids. They are also abundant in Tithonian levels of the Swiss Alps in facies similar to the Balearic ones, according to Lombard.

The marly limestones containing *Nannoconus* are, then, very pure, typically pelagic formations, characteristic of a warm sea in which, among other organisms that have left no traces, Radiolaria,

Tintinnids, *Globochaete* and other nanno-planktonic algae, such as the Coccolithophoridae, developed in immense numbers. It is very possible that *Nannoconus* itself was a planktonic organism, as its enormous accumulation solely in pelagic facies tends to indicate, but on this point nothing certain is known since it is not represented in existing seas and no kind of comparisons between this form and living ones can be made. Radiolaria predominate in some beds, Tintinnids in others. And as soon as the deposits reflect marked near-shore influences *Nannoconus* disappears and the facies is replaced by another kind of sediments, whose matrix is a fine, granular calcite and in which *Nannoconus* is clearly seen to be dying out. We must remember that in Majorca the marly facies with Radiolarians begin during the Upper Lias and persist with great uniformity up to and including the Barremian. True *Nannoconus* limestones, however, first occur only in the uppermost strata of the Tithonian. Their appearance coincides undoubtedly with a progressive increase of depth in the entire zone of subsidence and a stricter prevalence of a very pure, pelagic regime.

Nannoconus facies, then, make their appearance at the end of the Tithonian in the domains of the Sierras Béticas and the Balearic Islands, their first, very typical beds resting on the pink or varicoloured limestones called by French geologists "fausses-brèches." The lowest strata of the latter are rich in Radiolaria, *Globochaetes* and Tintinnids, this last represented by three species, two of which—*Calpionella alpina* Lorenz and *C. elliptica* Cadisch—are extremely abundant. "Fausses-brèches" are widespread in the Spanish Alps. They are fine-grained sediments whose tranquil formation was interrupted by strong submarine currents that shifted them in part upon themselves and produced the pseudo-brecciated structure to which they owe their name. They are composed largely of organic detritus.

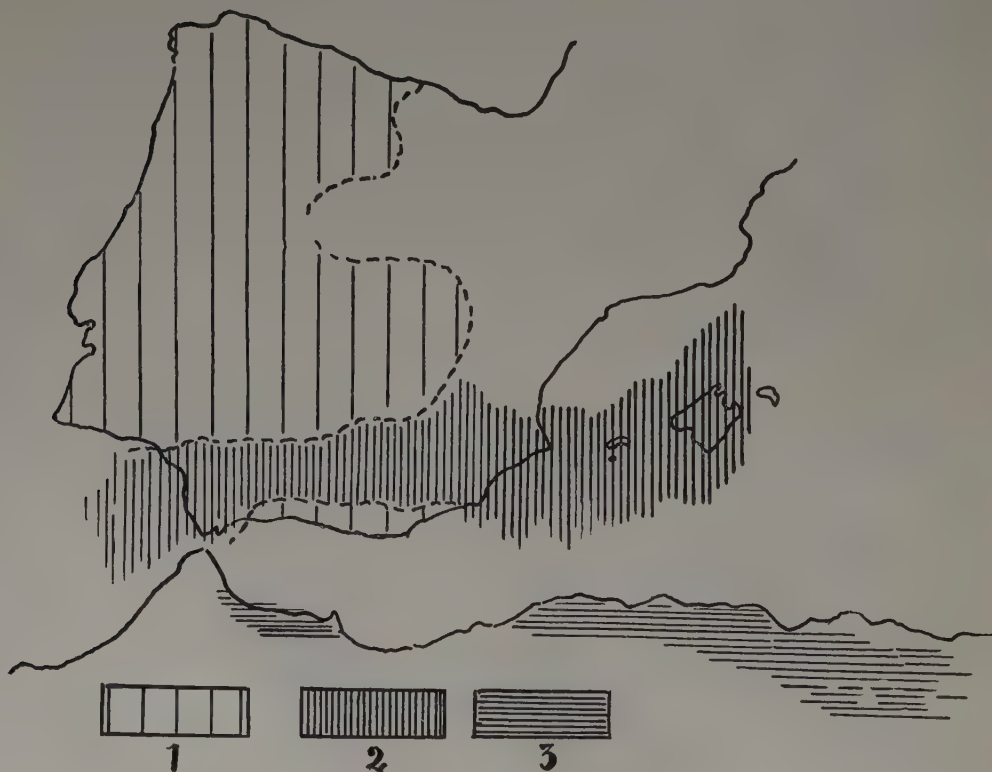


FIG. 1.

1. Iberian meseta. 2. Limestone "fausses-brèches" facies along the Spanish Alps, with fossil Tintinnids (=Calpionellae) and *Nannoconus* in their uppermost beds. 3. North African Tithonian with Tintinnids, but in which beds with *Nannoconus* have not yet been observed.



FIG. 2.

The great sedimentary regions of the Western Mediterranean during the Barremian-Aptian. Occurrence of *Nannoconus* limestone facies in the bathyal depths of North Italy, Provence, Balearic Islands (Ibiza and Majorca) and Southern Spain.

1. Deep-sea sedimentation. 2. Marly-limestone facies with *Nannoconus*. 3. Zone of the "schistes lustrés" of the Alps and Corsica. 4. Neritic sedimentation with Rudists. 5. "Flysch" facies of North Africa, with areas of deep-sedimentation. 6. Wealden facies of the Iberian peninsula. 7. Neritic facies of North Africa.

For the Spanish regions that have been studied, we know that the "fausses-brèches" contain diverse Tintinnid species and that *Nannoconus* first occurs in their highest levels. For similar facies in North Africa (Fig. 1), however, I can only note that in certain particular deposits Tintinnids occur in abundance, as the studies of Solignac in Tunis, Laffitte in Algiers and Blumenthal in the zone of Alhucemas (Spanish Rif) have shown.

The extension, from the data thus far known, of the pelagic facies containing *Nannoconus* around the Western Mediterranean basin during the Barremian is shown in Fig. 2. The sediments are seen to be distributed throughout the deep-sea zones of the Mediterranean geosyncline. Surrounding formations are also at times deep-sea but with marked terrigenous influences, and they finally give way to strongly calcareous, detritic sediments with, at some localities, large colonies of Rudists. It is not known, so far as I am aware, if facies with *Nannoconus* occur in the bathyal deposits of North Africa, Tunis and Algeria. Future investigations may possibly reveal their existence there.

Wherever *Nannoconus*-bearing facies have been found, it has been demonstrated that they first appear during the uppermost Tithonian and persist during the entire Neocomian s. l., reaching at times, as in the Balearics, the base of the Aptian, where they then disappear rapidly because of an abrupt change in the conditions of sedimentation.

Up to the present *Nannoconus* formations do not seem to have been cited from the Upper Cretaceous and the data we have as to their importance and extension in Lower Cretaceous beds of Eastern Mediterranean bathyal zones are still limited, unless my information is incomplete, to the work by the Rumanian geologist Murgeanu (1931) cited above.

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SOME FUNDAMENTAL ASPECTS OF CORRELATION (SUMMARY)

By A. E. TRUEMAN

THE discussions which took place during the three sessions held by Section "J" emphasized the great range of detail, applying to countries covering nearly the whole of the world, which had been brought to their notice. It is, of course, impossible to collate many of these details in any brief summary. But the discussion emphasized several significant features in the ways in which palaeontology and stratigraphical geology were being developed to deal with problems of zonal correlation.

In the first place it was clear that palaeontologists were greatly extending the variety of organisms which they were bringing into use for the purposes of correlation. The great increase in the attention which was being paid to foraminifera during the past generation was of outstanding significance; Mr. A. N. Thomas provided them with an account of some of the problems raised in the use of those organisms in detailed correlations where there were variable facies. Similarly in more recent years the use of conodonts had made very great progress; they were indebted to Messrs. Branson and Mehl for their exposition of this subject. Dr. Yen was seeking to develop the use of such difficult organisms as the freshwater molluscs, Professor Harris and Dr. Wilson had illustrated the ways in which the micro-floras could be used, and Dr. Dijkstra had indicated the utility of megaspores in Carboniferous correlation. There was little doubt that future work would show further extensions of all these branches of study.

In the second place many of the contributions had shown that organisms which at first sight would have appeared unsuitable could be used as a basis for local correlation. The work of Dr. Wilson in tracing thin horizons in the Tertiary deposits of the U.S.A. illustrated these possibilities. Indeed, there might be a temptation to suggest that correlation over limited basins, and in some cases over quite extensive areas, was proving much easier than might reasonably have been expected. But as Professor Renier had said, local correlations (often dependent on facies) must not be expected to be capable of unlimited extension. The fact that these local correlations broke down when they were carried too far did not mean that they were not valuable, but palaeontologists must always be aware of the danger which arose from the apparent ease with which local correlations could be made. As Professor Renier had made clear, inter-continental correlation involves many problems which geologists must bear in mind when reaching conclusions.

Another feature in the discussions was the realization that both faunal and floral evidence is valuable, and that those studying these different types of material must be prepared to take into account the results of their colleagues. This was rather a different position from that which existed in some countries a generation ago; it is clear, however, that when properly understood, and with due allowance for facies changes, the faunal and floral evidence must lead to the same conclusion. Where the evidence is incomplete, however, it is better to emphasize that correlations are only tentative, as Professor George and Mr. Lacey had indicated in the case of the Lower Carboniferous rocks of Britain.

The problems of correlation of distant areas are less difficult in many cases than the creation of a satisfactory classification of the stratigraphical column applicable to the same areas. This is clearly seen in the account which Dr. Librovich had given of the Lower Carboniferous rocks of the U.S.S.R. He emphasized, as other workers had done before, that in Russia the Namurian is more conveniently classified with the Lower than with the Upper (or Middle) Carboniferous, though in Western Europe generally, as in Britain, the main part of the Namurian passes upwards into the Upper Carboniferous

and forms a natural part of it. Yet the faunal evidence shows that essentially the Namurian of Russia corresponds with the Namurian elsewhere; correlation is possible but classification into major divisions at present raises greater difficulties.

This type of problem arises when most System boundaries are being considered. It appears that the more finely it is sought to divide the stratigraphical column the smaller the horizontal distances over which the divisions can be accurately identified (with some notable exceptions); world correlation must be based on broad divisions, but even then the boundaries between these divisions may become increasingly vague as the distance over which they are traced grows.

It is important that students should realize these points. There is perhaps a tendency for students still to inherit something of the mind of the old geologists who believed that catastrophic changes terminated the deposition of each System. They still tend to think too frequently that there is a real distinction between Devonian faunas and Carboniferous faunas which should be world-wide, as if a person who had lived through that episode in whatever part of the world would have noticed some change in faunas. Expressed in that way, the unreasonableness of this view is apparent, but geologists still too frequently try to find a boundary which they hope will be world-wide. Ought we not to recognize that in seeking a world classification with such firm boundary lines we may be chasing a Will o' the Wisp?

DISCUSSION

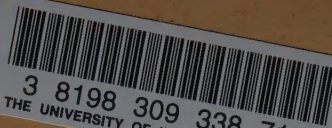
R. C. MOORE considered that it was important to note that so many stages were recognizable in so many widely separated areas, and that that was more important than that the boundaries of stages were indefinite in a number of places.

CHR. POULSEN proposed that when the correlation of formations of different regions was certain the older of the formational names in question should be considered valid, and superfluous names should be omitted in order to simplify the stratigraphical correlation tables.

O. H. SCHINDEWOLF said: "Die Vorträge und Diskussionen in unserer Sektion haben gezeigt, welche Fülle verschiedener Tier- und Pflanzengruppen mit Erfolg zu biostratigraphischen Zwecken herangezogen werden kann. Die beschränkte Anzahl der früheren klassischen Leitfossilien und leitenden Organismengruppen ist in den letzten Jahrzehnten beträchtlich erweitert worden. Die Richtigkeit unseres Grundprinzips der biologischen Chronologie und Stratigraphie hat keine Erschütterung erfahren, abgesehen von Fällen falscher Bestimmungen und von Urteilen aus zu engem lokalen Gesichtswinkel, wofür A. Renier Beispiele vorlegte. Wir werden daher auf dem eingeschlagenen Wege fortfahren und unsere Stratigraphie immer mehr zu verfeinern suchen: (a) durch vertiefte Untersuchungen und Unterscheidungen der bisher benutzten Leitformen, (b) durch weitere Heranziehung bislang noch nicht ausgewerteter Organismengruppen. Alsdann aber obliegt uns die Aufgabe, diese auf verschiedener Basis gewonnenen und zunächst parallel nebeneinander stehenden Gliederungen zu koordinieren und in unsere Standard-Gliederung einzuordnen. Hinsichtlich der Grenzziehungen werden wir häufig auf Kompromisse und Konventionen angewiesen sein. Soweit solche Fragen durch Kongressbeschlüsse erledigt sind, sollte tunlichst nicht davon abgewichen werden, wie L. S. Librovich es gegenüber den Beschlüssen des Heerleiner Karbon-Kongresses getan hat. Wenn ein Autor glaubt, mit triftigen Gründen solche einmal getroffenen Entscheidungen anfechten zu müssen, sollte diese Frage erneut vor einem Kongress gebracht und dann verbindlich entschieden werden."

H. DIGHTON THOMAS referred to the development of trends of evolution as worked out by A. E. Trueman in Liassic *Gryphoeae* and by W. D. Lang in corals. Although trends could, and did, recur in a group at widely separated intervals of time, nevertheless they often seemed to be run through contemporaneously, or nearly so. Thus we were often able to correlate faunas of different areas by the stages of evolution reached. T. C. Yen's work appeared to demonstrate such a case. One would like to know the cause of such parallel developments in separated basins. The speaker also referred to the difficulty of the exact identification of species of hexacorals, especially, though not only, in thin sections. It often became apparent that a fossil "species" was really a species-group, so that caution was needed in using them in correlation of the narrower stratigraphical units.





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LIST OF THE PARTS OF THE REPORT OF THE EIGHTEENTH SESSION

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- PART XII. Proceedings of Section L: Earth Movements and Organic Evolution.
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- PART XIV. Proceedings of the Association des Services géologiques africains.
- PART XV. Proceedings of the International Paleontological Union.